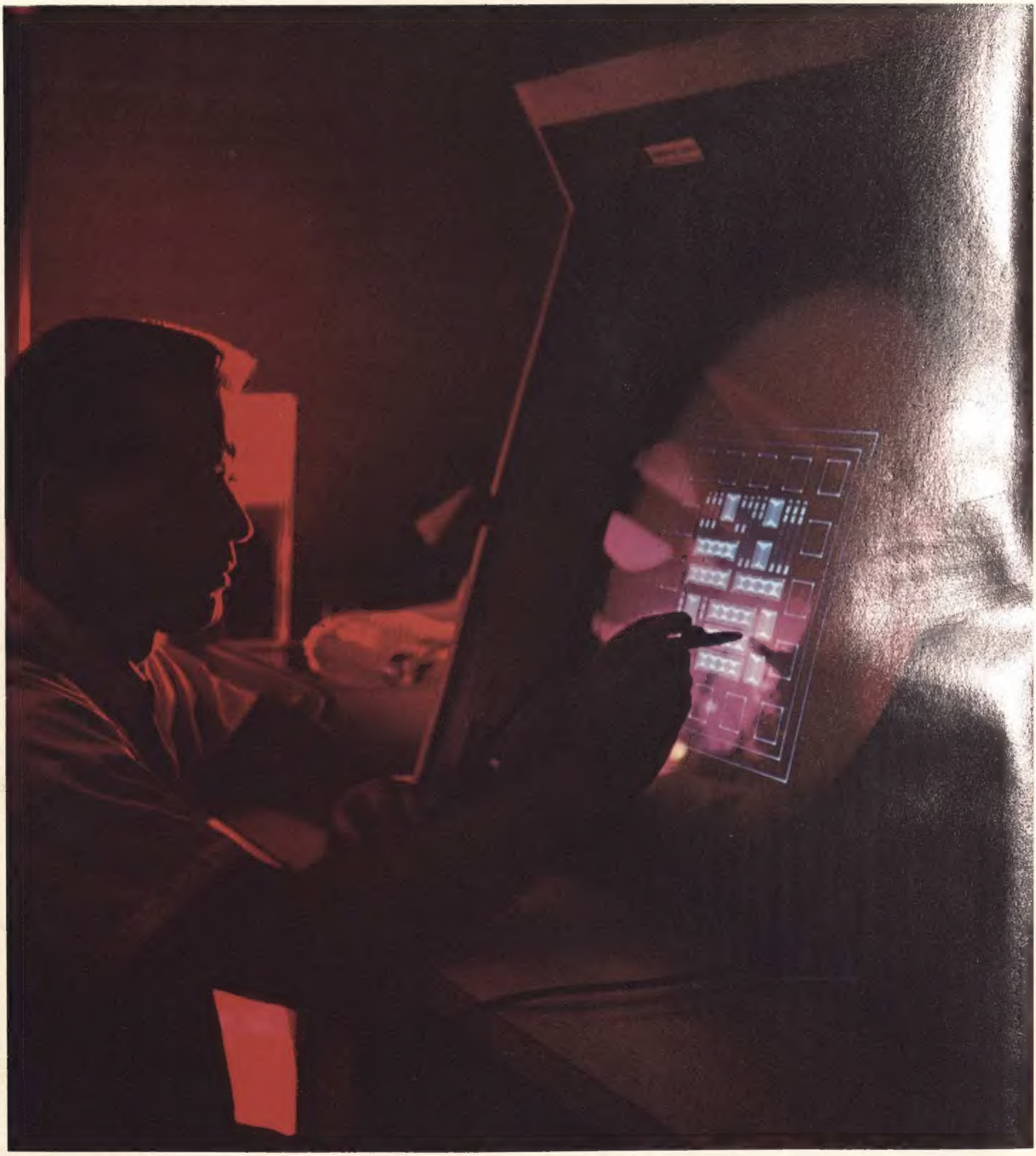
19

Illustrated World of Science Encyclopedia

Biography I:
A to LIEBIG

THE WORLD OF SCIENCE



THE WORLD OF SCIENCE

VOLUME

19

A *to* Liebig

BIOGRAPHY I

with

The Illustrated Science Dictionary

CREATIVE WORLD PUBLICATIONS, INC.
CHICAGO

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APPLETON, SIR EDWARD VICTOR (1892–1965)

For his studies of the Earth's outer atmosphere the British physicist Sir Edward Victor Appleton received the 1947 Nobel Prize in physics. As a radio officer in World War I, he became acquainted with some of the technical problems involved in transmitting radio signals. This interest helped shape his career.

Today scientists estimate that the ionosphere, or outer atmosphere, is—very roughly—50 to 200 miles above the Earth. Early in the twentieth century, scientists A. K. Kennelly and O. Heaviside theorized that this layer of atmosphere contains electrically charged particles. In the 1920s Appleton performed experiments to demonstrate the existence of such a layer (then called the Kennelly-Heaviside layer) and actually made measurements of it.

Appleton had long-range radio in mind. The electrically charged particles in the ionosphere bounce radio signals back to Earth and therefore prevent them from simply floating into space. Appleton determined the maximum height at which reflection of such signals takes place and the necessary wavelength of the signals. He eventually discovered that at some wavelengths the signals penetrate the Kennelly-Heaviside layer but are reflected off the next layer, which is sometimes called the Appleton layer.

His studies of the outer atmosphere proved valuable in another practical way. His early work is said to have contributed to the development of radar.

Appleton was born in Bradford, Yorkshire, England. He was educated at St. John's College, Cambridge, and became a fellow of Cambridge in 1919. In 1924 he became professor of physics at King's College, the University of London. In 1936 he was appointed professor of natural philosophy at Cambridge. During World War II he was secretary to the British government's Department of Scientific and Industrial Research and carried on research involving the atomic bomb and radar. In 1949 he was appointed principal and vice-chancellor of Edinburgh University and held that post until his death.

In his lifetime Sir Edward received many honors in addition to the Nobel Prize. He was awarded honorary degrees from sixteen universities and in 1941 was knighted. He served as president of the International Scientific Radio Union from 1938 to 1954. Also, he was made a fellow of the Royal Society in 1927 and received its Hughes Medal in 1933.

ARCHIMEDES (287?–212 B.C.)

The greatest mathematician and scientist of ancient times was Archimedes. Nobody matched his scientific accomplishments until mid-seventeenth century, the time of Sir Isaac Newton. His contemporaries avidly followed the illustrious Greek's activities and discoveries. Those admirers supplied colorful, if sometimes apocryphal, stories about his life. His works are well documented, however, for he left many written records.

Archimedes was born in Syracuse, Italy, the son of Pheidias, an astronomer. He was educated in Alexandria, Egypt, but returned to Syracuse, where he enjoyed the patronage of King Hieron II. Although his genius as an inventor has always captured the popular imagination, the achievements that Archimedes considered his most valuable were in mathematics.

He explained his approach to scientific problems in *The Method.* The original of this work was discovered early in the twentieth century. In *The Method,* Archimedes affirms that mathematical demonstration must be a rigorous process, derived with absolute logic from preceding premises, definitions, and theorems. This conforms with the principles that all mathematicians follow. Archimedes, however, held that a mathematician is entitled to use any means at his disposal to inspire an idea that may lead to mathematical invention. He did not hesitate to draw geometric figures and then take measurements in order to discover whether any relationship between their elements could be demonstrated. Most mathematicians would hesitate to reveal that they discovered a mathematical relationship after first taking measurements, but Archimedes saw no discredit in disclosing his starting point if he could demonstrate results with strict logic.

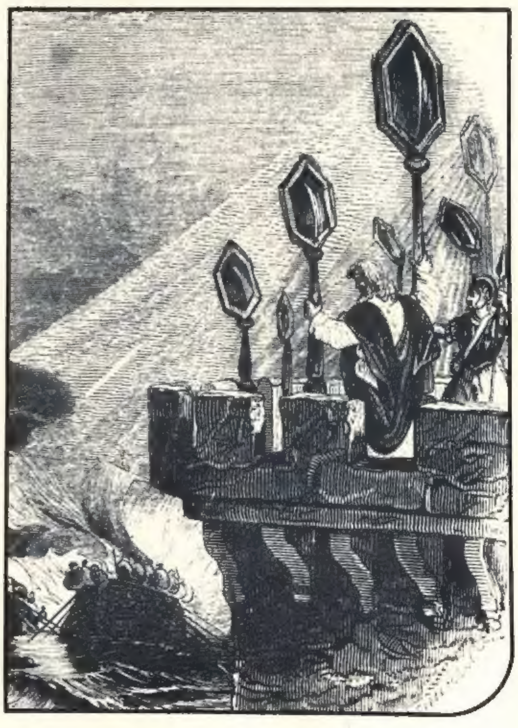
Archimedes discovered many basic principles of geometry and developed a method similar to modern integral calculus for computing the surface and volume of geometric figures. During his time, a number of mathematicians sought a formula or a geometric construction to determine the relationship between the circumference and diameter of a circle—a ratio known as pi. The value that Archimedes calculated for pi was the best obtained in the classical world. In devising a system of arithmetical notation with which very large figures could be written concisely, Archimedes achieved results for which methods of calculation were not evolved until the eighteenth century.

In the field of physics he was the first to state the laws governing leverage. It is told that he said, "Give me a place to stand, and I will move the Earth." To illustrate for King Hieron, Archimedes is said to have provided the king with a mechanical device that enabled him to move a large, loaded ship by himself.

The water screw invented by Archimedes is still used in Egypt for irrigating fields. This mechanism consists of an inclined cylinder containing a screw as long as the cylinder and large enough to touch its walls throughout. When the

Archimedes

Among Archimedes' inventions were many ingenious machines for use in warfare. One of these consisted of large mirrors that set fire to the sails of ships by focusing the sun's rays on them.



screw is turned, it draws the liquid up from the bottom of the cylinder.

One of the most famous stories about Archimedes stems from his discovery of the principle of buoyancy: the force that tends to push a partially or totally submerged object out of a liquid is equal to the weight of the liquid displaced by the object. King Hieron is supposed to have asked Archimedes to determine whether he had been cheated with a crown he had ordered to be made of gold. He suspected that it contained silver as well. Archimedes was puzzled, the story goes, until he stepped into a bath one day and noticed that the water ran over. It occurred to him that if the crown were made of pure gold, it should take up the same amount of space as an equal weight of pure gold. If he placed the crown and the equal weight of pure gold in turn into a full tub of water, equal volumes of water should overflow. He purportedly was so overjoyed when the solution struck him that he ran home naked through the streets, shouting, "Eureka, Eureka," Greek for "I have found it, I have found it."

Archimedes is credited with inventing weapons of war that delayed the fall of Syracuse to the Romans for three years. In the general massacre that followed the city's capture in 212 B.C., Archimedes was slain while drawing mathematical figures in the sand. The Roman general, Marcellus, who had ordered his men to spare Archimedes and his house, lamented the death, provided an honorable burial for the great man, and befriended his survivors.

ARISTOTLE (384–322 B.C.)

One of the greatest thinkers and scholars of all time was the Greek philosopher Aristotle. He was a genius whose writings have been profoundly influential in many branches of learning. His biography in the *Encyclopædia Britannica* fills twenty pages, an indication of the breadth and depth of his work.

Aristotle had a command of all the knowledge of his day. He divided this knowledge into such subject fields as physics, psychology, metaphysics, rhetoric, politics, and logic. He made his least claim to fame probably in the area of mathematics, but his logic was closely related to the philosophy and background of mathematics.

His first scientific love, however, was biology, and his greatest contribution to that field can be summarized in one word: *classification*. Animal species were his particular subject; in his writings he classified more than 500 species. One system of classification was based on whether or not animals had red blood; very roughly under this system the animal species broke down into the two large groups now called vertebrate and invertebrate. Another system of classification devised by Aristotle, this one more sophisticated, was based on reproduction; animals were divided according to their methods of reproduction, from the complex viviparous animals down to those who reproduced through spontaneous generation.

In Aristotle's work the animals were arranged in a progressive sequence, or "ladder of nature." It contained the germ of the theory of evolution formulated much later by Charles Darwin, but Aristotle mistakenly rejected the idea that any species could change or evolve into a different species.

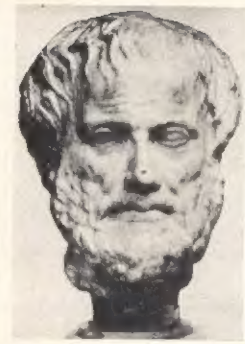
Even today Aristotle is considered one of the greatest biologists of all time. He was thorough and meticulous in making his classifications, and he made many subtle distinctions. For example, he correctly grouped the dolphin with other warm-blooded animals rather than with fish.

In ancient times, it must be stressed, science was very theoretical and abstract. Systematic observation and experimentation were scarcely developed. There were only crude instruments available, and little importance was attached to them. Plato had maintained that the "real" world could not be seen or observed and could be known only philosophically. Aristotle rejected this view and insisted on the importance of direct observation of nature.

In physics Aristotle made no outstanding contributions. He accepted the four elements postulated by another philosopher: earth, water, air, and fire. To these four Aristotle added a fifth: aether. He considered that the heavenly bodies were all composed of aether. The heavens were very static, Aristotle believed.

A controversial question in ancient times was whether the world is round or flat. Aristotle spoke up firmly in favor of the Pythagorean idea that the world is indeed round. For a defense of this view he referred to the changing view of the stars as one travels.

Aristotle was born in Stagira, Greece. His father was court physician to the Macedonian king Amyntas. Aristotle went to Athens at the age of seventeen to study in Plato's Academy. After Plato's death Aristotle traveled and worked in other parts of the Greek world. Eventually Philip II, the new king of Macedonia and son of Amyntas, asked Aristotle to come and tutor his son Alexander. This was the same Alexander who later conquered the world and became known as Alexander the Great. When Philip died and Alexander became king, Aristotle went back to Athens and taught at the Lyceum. He then started his own school, which came to be known as Peripatetic (walking about) because of its casual atmosphere.


Aristotle

Only 47 of his treatises survive, though it is believed that he wrote more than 100. Some of his best-known works are the 5 treatises on animals, including *History of Animals*. Also well known are the *Organon*, on logic, and *De Anima*, on psychology. Other areas treated by him are the physical world and philosophy.

ARMSTRONG, HENRY EDWARD (1848–1937)

The British chemist Henry Edward Armstrong was renowned as a teacher. A staunch advocate of the heuristic (discovery) method of teaching, he inspired many pupils who later distinguished themselves in the field of chemistry. Basing his instruction on the periodic table of Dmitri Ivanovich Mendeleev, he was ahead of his time, since the table was not commonly accepted.

As a result of his research, he proposed a centric formula for benzene. He also furnished basic information about the chemical structure of camphor and other terpenes. He wrote sixty papers on naphthalene derivatives; these studies had basic significance not only for the dyestuffs industry but also for organic chemistry in general.

Armstrong was born in Lewisham, Kent, England. He studied chemistry at the Royal College of Chemistry for two years and at Leipzig for three years. In 1871 he became professor of chemistry at the London Institution (later Finsbury Technical College). Eight years later, in 1879, Armstrong and W. E. Ayrton were asked to organize the teaching of chemistry and physics at the City and Guilds of London Institute. In 1884 he was named

professor of chemistry at the new Central Institution, which became the Central Technical College; he was retired from this post in 1911.

At the early age of twenty-eight, he was elected to the Royal Society. He gave long, distinguished service to the Chemical Society of London, serving as secretary from 1875 to 1893 and president from 1893 to 1895.

ARRHENIUS, SVANTE AUGUST (1859–1927)

A child prodigy who fulfilled his promise, Svante August Arrhenius of Sweden became one of the founders of modern physical chemistry. The thesis that he presented for his doctoral degree was so revolutionary in 1884 that his examiners almost refused it. Development of the same theory of electrolytic dissociation won Arrhenius the 1903 Nobel Prize in chemistry.

Part of his theory forms the basis for all later theories of the conductivity of solutions. The theory states that when some substances are dissolved in water or other suitable solvents, their molecules split into ions, or electrically charged particles. Most scientists in the 1880s could not conceive of electrically charged particles. The committee at Uppsala University gave Arrhenius the lowest passing grade and awarded him his doctorate only because of his excellent scholastic record.

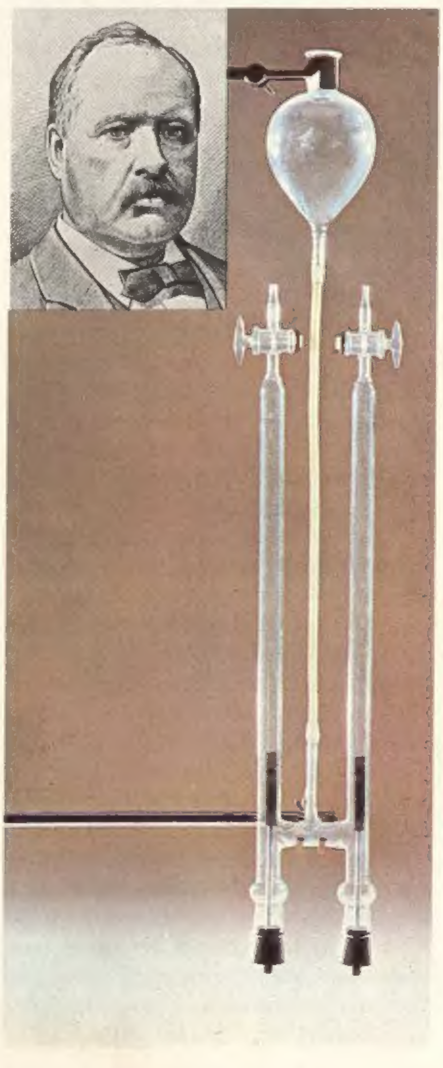
Before the turn of the century, radioactivity and the electron were discovered, and Arrhenius' theory was treated with respect in Sweden. Earlier, however, he had won the admiration and support of F. W. Ostwald and J. H. van't Hoff, other future Nobel laureates. Together the three fought for the new doctrines in physical chemistry.

Arrhenius was born at Wijk, near Uppsala, where his father was an estate manager. As a young child he showed remarkable mathematical ability and at the age of seventeen entered the University of Uppsala. Research facilities, however, were lacking there at the time; and in 1881 Arrhenius decided to go to Stockholm to work under the direction of Professor Erik Edlund on the study of solutions and electrolytes. After his disappointing experience with the committee that grudgingly granted him his doctorate, Arrhenius sent copies of his thesis to several prominent scientists of the time. F. W. Ostwald, who was then teaching in Riga, Latvia, was so impressed that he traveled to Sweden to talk with Arrhenius.

For the next five years Arrhenius worked with Ostwald, Van't Hoff, and other leaders in the field of physical chemistry. In 1891 Arrhenius declined a professorship at Giessen, Germany, and joined the faculty at Stockholm University as a lecturer. In 1895 he was elected to a professorship in physics. He was also rector of the university from 1887 to 1902. In 1887 he published a revised and improved version of his theory of electrolytic dissociation. He made a further contribution to physical chemistry in 1889 when he developed an equation for expressing the rate of a chemical reaction. Discovering the speedup of chemical reactions with the increase of temperature, he concluded that the reaction increases in proportion to the concentration of activated molecules. His basic idea is still sound.

In 1900 Arrhenius published a *Treatise on Theoretical Electrochemistry*, and in 1903 a *Treatise on Cosmic Physics*. Turning his attention to the chemistry of living matter, Arrhenius delivered a series of lectures in 1904 at the University of California. They were designed to illustrate how physical chemistry can be applied to explain reactions to toxins and antitoxins. These lectures were published in 1907 as *Immunochemistry*. Further Arrhenius contributions to biochemistry were published in 1915 as *Quantitative Laws in Biological Chemistry*.

By the amount of electrolysis produced, a voltameter measures the quantity of electricity passed through a conductor. Electrolytic dissociation—the splitting up of the molecules of certain substances into electrically charged particles (ions)—was discovered by the Swedish chemist Svante August Arrhenius.



Meanwhile, in 1912, he had published *Theories of Solutions*, based on a series of lectures that he gave at Yale University in 1911. Gregarious and good-humored, Arrhenius enjoyed traveling and visiting his colleagues abroad and entertaining them in Sweden. He was sought after as a companion and welcomed at scientific meetings everywhere.

Aside from chemistry, Arrhenius had wide interests that included cosmogony —the origination of the universe. In his *Worlds in the Making* (1908), he suggested that life is universally diffused in the form of spores that travel through space, driven by the pressure of radiation, and that a few finally land on planets that have reached a habitable stage. In his *Destinies of the Stars* (1918), Arrhenius discusses astronomical problems.

Arrhenius' Nobel award cited his special services to the development of chemistry. In 1905 he was appointed director of the Nobel Institute for Physical Chemistry at Experimentalfältet, near Stockholm. He held that post until shortly before his death. Arrhenius was made a member of the Royal Society of London in 1910. He was honored with many doctorates in Europe and abroad.

ASTON, FRANCIS WILLIAM (1877–1945)

Physicists and chemists involved with nuclear theory owe a great deal to British scientist Francis William Aston for his pioneering work. In 1922 Aston was awarded the Nobel Prize in chemistry for his discovery of many isotopes and for the development of the mass spectrograph.

To begin his career, Aston studied chemistry at Malvern College and Birmingham and Cambridge universities. With the discovery of x-rays and radioactivity in 1896, Aston was intrigued with new scientific possibilities and decided to go back to Birmingham to study physics.

In 1909 Aston began an assistantship at Cambridge under J. J. Thomson, who, with the help of his new assistant, worked out some proof that isotopes exist among

the stable elements. Isotopes are different atoms of the same element, with basically the same chemical behavior but with different physical properties (especially weight or mass).

After World War I, Aston worked on his own to develop an atomic-particle apparatus like the one Thomson had made, but with improvements. The instrument made photographs of the effects of electric and magnetic fields on rays. With this instrument, which Aston called the mass spectrograph because of its similarity to optical spectrographs, he was able to examine more than fifty elements for their isotopes. In the 1920s Aston made refinements in his original model.

All in all, Aston discovered 212 of the 287 naturally occurring isotopes. When he knew the mass and frequency of occurrence of an isotope, he was able to calculate the chemical atomic weight—another breakthrough.

Early in his work Aston formulated the whole number rule: the mass of an isotope can be expressed in whole numbers; for example, the name ^{235}U indicates a uranium isotope of a certain weight, one with less mass (or lighter in weight) than the isotope called ^{238}U. With improved equipment in the 1920s, Aston found that the whole number rule was not always true, but he also found a way to measure the small amount by which the mass varied from a whole number. This whole area of calculation is particularly crucial to contemporary nuclear scientists.

Aston was elected a fellow of Trinity College in 1920 and a fellow of the Royal Society in 1921. During his career he was honored with many medals, including the Hughes Medal of the Royal Society. Also, he was elected an honorary member of the Russian Academy of Sciences and of the Italian Accademia Nazionale dei Lincei.

AUDUBON, JOHN JAMES (1785–1851)

John James Audubon, naturalist and artist, has a special place in the hearts of those who love birds and, indeed, nature in general. Because he was so devoted to bird-watching, Audubon could not find the time to make a living. His wife supported the family by teaching, an unusual state of affairs in the early nineteenth century. He faced hardship and discomfort again and again on his expeditions searching for birds; and when rats destroyed some of his bird paintings, he simply painted them again.

John Audubon

Audubon's early drawings of North American birds depicted those of the eastern and southern United States. One of his finest works is *The Snowy Heron or White Egret*, with its background of South Carolina rice fields.

Audubon was born in Les Cayes, Santo Domingo (now Haiti), the son of a French naval officer. He spent his childhood in France but at the age of eighteen was sent to Pennsylvania to manage his father's business affairs. (Although he made some trips to Europe over the years to further his painting, basically he lived in the United States for the rest of his life.) In Philadelphia he studied bird migration; he banded the feet of birds in order to identify those that returned to the same area year after year.

In 1820 he began concentrating on a project: drawing all the birds of North America. He started with those in the eastern and southern United States; it was in this period that he made some harrowing journeys to find the birds he wanted. To find patrons or subscribers who would help him publish his works, Audubon journeyed to Europe in 1826. *The Birds of America* was published in sections beginning in 1827; the complete work consisted of five volumes with 435 hand-colored plates of 1,065 birds. Audubon represented the birds life-size in their native habitats. With the aid of Willian MacGillivray, he wrote *Ornithological Biography*, a text describing the birds in the illustrated work.

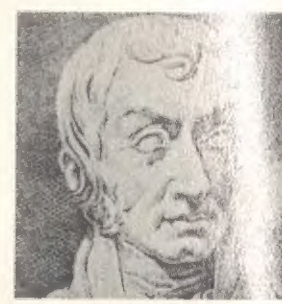
Lesser known is Audubon's interest in warm-blooded animals. He published a study of quadrupeds in 1845 and 1846.

Audubon was one of the first U.S. conservationists. In 1900 he was elected to the Hall of Fame for Great Americans. In his honor the National Audubon Society was founded in 1905 to promote conservation of all wildlife and of the environment. Activities of the society and its local branches include research and conducted wildlife tours.

AVOGADRO, AMEDEO (1776–1856)

It is intriguing that a very important law of modern chemistry was discovered by a lawyer turned physicist, Amedeo Avogadro, count of Quaregna and Ce-

Amedeo Avogadro



For about twenty years Avogadro taught mathematics, physics, and chemistry at Turin University.

retto. Avogadro's law states that equal volumes of all gases (at equal temperature and pressure) consist of equal numbers of molecules.

Avogadro's constant, sometimes called Avogadro's number, is the exact number of molecules in one mole (molecular weight in grams) in any substance. The number is always the same and is denoted by the letter *N*.

Avogadro was the first scientist to distinguish between atoms and molecules and to understand that molecules are clusters of atoms. When the hydrogen and oxygen in water are separated, the volume of hydrogen turns out to be twice that of oxygen. Avogadro said this was because each water molecule contains two hydrogen atoms for each oxygen atom. This idea was rejected by scientists of that day but is now known to be true. Not until after Avogadro's death did his work become recognized; the chemist Stanislao Cannizzaro propagated Avogadro's ideas and got his colleagues to realize the importance of distinguishing between atomic weight and molecular weight.

Avogadro was born in Turin, Italy, the son of a lawyer. He took his own law degree at an early age and practiced in the legal profession for several years. Meanwhile, he studied science in his spare time and even published a paper on his work. Eventually he abandoned his law practice and taught physics at the Royal College at Vercelli. In 1820 he was appointed professor of mathematics at Turin University and taught there at various times for a total of almost twenty years.

AXELROD, JULIUS (1912–)

The U.S. biochemist Julius Axelrod was awarded a share of the 1970 Nobel Prize in medicine or physiology for his contributions to a new understanding of regulatory mechanisms in the nervous system. Co-winners were Ulf von Euler of Sweden and Sir Bernard Katz of England, who also did independent, basic research in the chemistry of nerve transmission. All were cited for greatly stimulating the search for remedies against nervous and mental disturbances. (*See* Ulf Svante von Euler; Sir Bernard Katz.)

Axelrod's discoveries concerned the mechanisms that regulate the formation of noradrenaline in the nerve cells and also the mechanisms involved in the inactivation of noradrenaline after a nerve cell sends out an impulse. Noradrenaline, a chemical of the sympathetic nervous system, is closely related to adrenaline, the emergency hormone that is produced abundantly in time of great emotional strain or physical exertion. In finding the two key mechanisms for disposing of noradrenaline activity, Axelrod made possible the study of the effect of drugs on these mechanisms. He also made possible the investigation of derangements in the body's use of noradrenaline as manifested in some mental conditions.

A native of New York City, Axelrod received his bachelor's degree from the City College of the City of New York in 1933. He took his master's degree in chemical pharmacology at New York University in 1941 and his doctorate at George Washington University, Washington, D.C., in 1955. After working in New York City as a biochemist for fifteen years, Axelrod joined the National Heart Institute in Bethesda, Maryland, in 1949. Six years later he became chief of the section of pharmacology at the National Institute of Mental Health, also located in Bethesda.

Axelrod said that his work from the late 1950s through the late 1960s was influenced considerably by Von Euler's discovery in 1946 that noradrenaline is the nerve impulse transmitter in the peripheral nervous system.

BACON, ROGER (1220?–1292)

Because he insisted upon research and experiment in the study of nature, the medieval scholar Roger Bacon is sometimes described as the first modern scientist. He was a prophet as well, foreseeing mechanical transportation, on land and sea and in the air, and predicting circumnavigation of the world.

Bacon, who was born in England, tried to embrace all the knowledge of his time. He was interested in languages and in alchemy, astronomy, mathematics, and optics, though he considered theology the most important of all studies.

The dates and details of Bacon's life are not known for certain. They generally are deduced from remarks in his writings. One tradition holds that his birthplace was Ilchester in Somerset, and another, Bisley in Gloucester. He belonged to a wealthy family and had the advantage of early training in the classics and in arithmetic, geometry, music, and astronomy.

He studied and taught at Oxford University and later joined the faculty of arts at the University of Paris, France. After several years, he turned his attention to science. Returning to Oxford in about 1247, Bacon devoted his time and money to experimental research. At about this time, he joined the Franciscan order, but he was permitted to continue with his investigations into the nature of light and optics. Outspoken and querulous, Bacon made enemies inside and outside the order with his contempt for anyone who did not share his enthusiasms.

Some years after he joined the Franciscans, Bacon was transferred to Paris. In about 1266 Bacon wrote to Pope Clement IV, whom he had once met, proposing the introduction of science into Christian education. Thinking that Bacon had some finished plans to present, the pope commanded that he send more detailed information; but Bacon had in mind an encyclopedia of all the known sciences—a major project that depended upon the pope's sponsorship and funding.

Even after he became a Franciscan friar, Roger Bacon continued experimenting with real things, believing that knowledge could be better advanced that way than by poring over books. Because his ideas were much advanced for the time, he often met with curiosity and hostility.

Bacon prepared more information in short order, however. Within eighteen months, he wrote his ideas in the *Opus majus*, the *Opus minus*, and the *Opus tertium*. All this he had to do secretly under orders of the pope because of a Franciscan rule against unauthorized writing. The *Opus majus* was an effort to persuade the pope of the value of Bacon's proposed reforms. His hopes were never realized, however, because the pope died in 1268.

At some time between 1277 and 1279, Bacon was virtually imprisoned in Paris by his order. His attacks on other scholars and theologians and his excessive cre-

dulity about alchemy and astronomy appear to be the reason. The length of his imprisonment is not known, but he returned to Oxford in 1292 and died the same year.

BACON, SIR FRANCIS (1561–1626)

The English natural philosopher, statesman, and essayist Francis Bacon was born in London. He was the son of Sir Nicholas Bacon, keeper of the great seal.

Following family tradition, Bacon trained for a career in the service of the English crown. He was educated at Trinity College, Cambridge, and later studied law at Gray's Inn, London. In 1584 he entered Parliament. After repeated efforts, he finally won the favor of King James I and secured several appointments, as solicitor general (1607), attorney general (1613), and lord chancellor (1618). For his services he was created Baron Verulam in 1618 and viscount of St. Albans in 1621. Shortly thereafter he was accused of bribery and corruption in chancery suits. He pleaded guilty to the charges of bribery but insisted that his decisions or judgments had not been influenced thereby. Although he was spared severe punishment by the intervention of the king, his political career was brought to an end. In the few years remaining to him, he was a prolific writer, publishing many valuable works, as *History of Henry VII* (1622), *Historia ventorum* (1622), *Historia vitae et mortis* (1623), *Apophthegms* (1625), and a third, enlarged edition of the *Essays* (1625).

Besides his career as a statesman, Bacon also contributed greatly to experimental science by his philosophical works —*Advancement of Learning* (1605), the *Novum organum* (1620), and *De augmentis scientiarum* (1623), a fuller version of the *Advancement of Learning*, which, together with the *Novum organum*, was supposed to be part of his great unrealized work, *Instauratio magna*. Bacon intended the *Instauratio* to be a comprehensive classification of all accepted branches of knowledge according to the faculty of mind to which they belonged—memory, reason, or imagination. The *Advancement of Learning* argues against mysticism and calls for a realistic approach to the actual, apparent world through the study of science. In the *Novum organum*, Bacon dismisses Aristotle's deductive logic in favor of the Baconian, or inductive, method for investigating the causes of certain natural phenomena. This method involves going from the particular to the general—establishing the laws of science as generalizations based on the vast mass of observations that are still left after the exclusion of those elements that do not always occur with the phenomena in question.

Sir Francis Bacon

Some of Bacon's views were medieval —a result of his classical education—but he was unable to make experimental science fashionable and to couch it in such terms that other scholars could accept it. Some of them began to meet to discuss it, and these gatherings eventually developed into the Royal Academy.

Bacon's appreciation of the value of experiment finally led to his death. While riding in a carriage one day, he noticed the snow along the way and wondered whether it could delay putrefaction of living tissue. To find out, he alighted from the carriage, bought a chicken, and stuffed it with snow. While so engaged, he caught a cold, which turned into bronchitis and subsequently caused his death.

BAER, KARL ERNST VON (1792–1876)

The biologist and embryologist Karl Baer, who discovered the notochord and the mammalian ovum, was born in Piep, Estonia. He was descended from German nobility.

At first he was trained for a military career; but in 1810 he entered Dorpat University as a medical student, graduating in 1814. Upon discovering that he did not like being a practitioner, he moved to Germany to study embryology and anatomy under Professor J. I. J. Döllinger (1774–1841) at the University of Würzburg. In 1817 he settled in Königsberg as a prosecutor in anatomy at the invitation of a former teacher of his, K. F. Burdach, who had become professor of anatomy there. Two years later he became associate professor of zoology, and in 1822 a professor. He stayed at Königsberg until 1834, when he was appointed librarian to the Academy of Sciences of St. Petersburg.

The rest of his life was spent in various fields of research—anthropology, ethnography, and geology, as well as biology. Through the years he built up an extensive collection of information about the fauna and flora of the polar regions, as a result of which he was named the leader of an Arctic expedition in 1837. After more than thirty years in St. Petersburg, he returned to Dorpat.

It was while at Königsberg that Baer made the discovery for which he is famous—that of the mammalian ovum within the Graafian follicle. In 1827 Baer discovered the mammalian egg as a yellowish spot inside the follicle of a dog. Up to that time, there had been many misconceptions regarding the mammalian egg, though the eggs of many lower animals were known. The Dutch physiologist Regnier de Graaf (1641–1673) thought that the follicles themselves were the eggs, while to the Swiss biologist Albrecht von Haller (1708–1777) the egg was formed by coagulation from the fluid of the Graafian follicle.

While doing research on the embryo chick, Baer discovered the notochord, a cylindrical cord running along the back. Primitive fishlike creatures possess this structure throughout life, and Baer showed that it is also present in the early embryonic stages of all vertebrates, indicating a linkage between vertebrate embryos and primitive prevertebrate creatures. As a result, all animals that possess a notochord at some stage of their development are grouped together in the phylum Chordata.

Besides discovering the mammalian ovum and the notochord, Baer advanced the germ-layer theory. According to Baer, the various organs develop by differentiation from four germ layers in the developing egg after the primary stage of cleavage of the fertilized egg. This theory was later modified by the Polish-German physician Robert Remak (1815–1865), who pointed out that there are actually only three germ layers, since the middle layers form a single structure.

Baer also formulated the law of corresponding stages, according to which all vertebrates—both higher and lower animals—pass through similar stages and resemble one another during early em-

Karl von Baer

ic development. Baer reached this usion after some specimen em- had been mixed up and he was un- tell which was which. Although aw was instrumental in the inter- ion of evolution, Baer could not ac- Darwinism and the theory of un- descent with modification. In- he believed in the archetypal that creatures evolve from some ive archetype, each following its ourse of development.

r's most important writings are *de Ovo Mammalium et Homini* ("On the Origin of the Mam- and Human Ovum"; 1827) and *ie Entwickelungsgeschichte der* ("History of the Development of ", 1828, 1837). In addition, he ote *Development of Fishes* (1835) mongraph on the fishes of the and Caspian seas.

YER, JOHANN FRIEDRICH HELM ADOLF VON (1835–1917)

his work in synthetic organic istry—in particular the synthesis of ligo—Johann Friedrich Adolf von ever received the Nobel Prize in chem- stry in 1905. His synthesis of indigo had ler implications for the synthesis of dye in general.

In 1863 Baeyer discovered barbituric acid. The chemistry of barbiturates, or modern sedative drugs, was worked out in detail by one of Baeyer's students, Emil Fischer, a Nobel Prize winner in 1902.

Underlying Baeyer's work was his faith in structure theory, which had been outlined by the chemist F. A. Kekulé. For some time, chemists had believed that it was impossible to discover the structure of molecules or the way in which atoms combined to make molecules. Kekulé refused to accept this idea and formulated theories on how carbon atoms combine in various ways to form molecules; but he was unable to broaden the applications of his structure theory, and Baeyer became the first organic chemist to make full use of it.

Baeyer's strain theory, for example, deals with rings of carbon atoms. He explained why rings of five atoms and six atoms (of carbon) occur more frequently than those of less than five or more than six.

Baeyer, born in Berlin, Germany, was the son of the head of the Geodetic Institute, Johann Jacob von Baeyer. He studied chemistry under the renowned R. W. Bunsen. In 1858 he took his doctorate at Berlin. He taught at the Gewerbe School in Berlin from 1860 to 1872. His next post was that of professor of chemistry at Strasbourg, France, from 1872 to 1875. Then he became the successor to the respected chemistry professor Justus von Liebig at Munich.

BANTING, SIR FREDERICK GRANT (1891–1941)

The first specific treatment for diabetes mellitus was made possible when Canadian Frederick Grant Banting, with Charles H. Best, isolated the hormone insulin in 1921. Together with J. J. R. MacLeod, whose laboratory he had used, Banting was awarded the 1923 Nobel Prize in physiology or medicine. Banting divided his share of the award with Best. (*See* John James Rickard MacLeod.)

Working as a team from May until November of 1921, Banting and Best succeeded in isolating insulin from the pancreas of experimental animals provided by MacLeod along with his physiological laboratory at the University of Toronto. A young chemist, J. B. Collip, helped them purify the extract and make it usable by diabetic patients. MacLeod, whose most important work was on the nature of control of carbohydrate metabolism, shared his Nobel Prize with Collip.

Banting, the son of a farmer, was born in Alliston, Ontario, Canada, and educated at the University of Toronto. He was awarded the Military Cross for gallantry in the field while serving as a medical officer in World War I. After the war, he entered practice as a surgeon in London, Ontario. He grew interested in diabetes, a chronic disorder of the process by which insulin controls sugar metabolism. When the pancreas does not produce enough insulin, the glucose level in the blood becomes abnormally high. Untreated, diabetes leads to coma and death. With insulin, it can be controlled.

Sir Frederick Banting

Although it was long known prior to Banting's experiments that removal of the pancreas in experimental animals caused a condition similar to diabetes, all attempts to extract insulin from the pancreas had failed. The source of insulin is in the groups of tiny cells known as Islets of Langerhans, which are scattered throughout the pancreas. In 1920 Banting conceived that tying off the pancreatic ducts would destroy the whole gland except for the islets. If they were responsible for secreting the crucial hormone, it could then be extracted.

The announcement of success was made in 1922, and in 1923 Banting became head of the new Banting and Best Department of Medical Research created at the University of Toronto by the government of Ontario. In the same year, the Canadian Parliament voted Banting an annuity of $7,500 to support further research. The Banting Research Foundation was established in 1924, and the Banting Institute for Medical Research was opened in 1930.

Banting was elected a fellow of the Royal Society of Canada in 1926 and of the Royal Society of London in 1935. He was knighted in 1934.

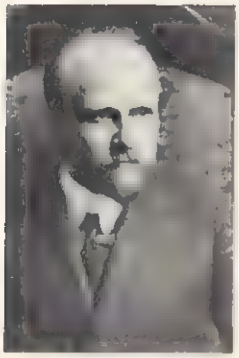
From 1939 until his death, Banting served as a major in the Canadian army, coordinating medical research for Canada and Great Britain. While on a mission to England in 1941, he was killed in an airplane crash at Newfoundland.

BÁRÁNY, ROBERT (1876–1936)

Robert Bárány, an Austro-Swedish physician, made discoveries about the body's balancing apparatus, for which he won the 1914 Nobel Prize in physiology or medicine. He also devised methods for diagnosing and correcting diseases of the inner ear.

Bárány, who was of Hungarian descent, was born in Vienna and studied medicine there. In 1903 he became an assistant at the ear clinic of Vienna University. Six years later, in 1909, he was named lecturer on otological medicine and in the same year worked out the indication test for examining the interrelationship of inner ear, brain, and spinal marrow.

In World War I, Bárány served in the Austro-Hungarian army as a medical officer. He was captured by Russia in 1915 and released a year later because of a knee injury. He moved to Sweden and, from 1917 until his death, was professor at Uppsala University, where he headed the ear, nose, and throat clinic. Among his innovations in the treatment of ear



Robert Bárány

disease was a useful device for isolating the auditory performance of one ear by creating noise in the other. He developed a test for evaluating coordination in order to detect brain lesions. A rotating chair used in aviation medicine to test the sense of balance is named the Bárány chair in his honor.

Bárány published numerous treatises on subjects in his field and related ones. He was elected to membership in many scholarly societies. Besides the Nobel Prize, he won the Guyot Prize of the University of Groningen in The Netherlands and the Swedish Medical Society Medal.

BARDEEN, JOHN (1908–)

In 1956 the American theoretical physicist John Bardeen shared the Nobel Prize in physics with William B. Shockley and Walter H. Brattain, his colleagues at the Bell Telephone Laboratories. They were awarded the prize for their invention, in December 1947, of the transistor, an electronic amplifying device utilizing solid-state semiconductors, which were smaller, less fragile, and more efficient than conventional vacuum tubes. (*See* Walter Houser Brattain; William Bradford Shockley.)

Besides his contribution to theoretical understanding of semiconductors, Bardeen is also known for his theory of the superconductivity of some metals—the vanishing of all trace of resistance to flow of electricity at low temperatures. He first became interested in superconductivity in the mid-1930s, but this interest was interrupted until 1950 by World War II and by his position with the Bell Telephone Laboratories. In 1957 Bardeen and his associates constructed a model in which electrons coupled in pairs by their interaction with the lattice vibrations gave rise to many of the observed features of the superconducting state. According to Bardeen, fundamental to superconductivity is a pairing interaction between the electrons resulting from an effective attraction induced by the interaction between electrons and atomic vibrations.

John Bardeen was born in Madison, Wisconsin. He received both his bachelor's and master's degrees in electrical engineering from the University of Wisconsin in 1928 and 1929, respectively, and a doctorate in mathematics and physics from Princeton University in 1936. Before joining the Bell Telephone Laboratories as a research physicist in 1945, he was a postdoctoral fellow at Harvard University, an assistant professor of physics at the University of Minnesota, and, during World War II, principal physicist at the U.S. Naval Ordnance Laboratory, Washington, D.C. It was while at the Bell Telephone Laboratories that he helped with the invention of the transistor. In 1951 he became a professor of physics and electrical engineering at the University of Illinois.

The transistor, a simple, solid-state amplifier, was invented late in 1947 by John Bardeen, Walter Brattain, and William Shockley. Because of its small size and efficiency, this electronic device soon replaced the vacuum tube and found wide usage in computers and communications systems.

For his contributions to solid-state and low-temperature physics, especially regarding semiconductors and superconductivity, Bardeen received many honors. He was awarded the Ballentine Medal of the Franklin Institute (1952), the Buckley Prize (1954), and the Scott Medal (1955). In 1954 he was elected a member of the National Academy of Science.

BARKLA, CHARLES GLOVER
(1877–1944)

X-rays were discovered in 1895 by Wilhelm Conrad Roentgen. This discovery generated intense excitement in the scientific community and opened up a new area of study and research. One of the scientists who provided valuable studies of x-rays was the English physicist Charles Glover Barkla, who received the Nobel Prize in physics in 1917. Barkla was one of several men whose efforts reached culmination in the work of the great physicist Niels H. D. Bohr. (*See* Niels Henrik David Bohr.)

Roentgen mistakenly believed that x-rays consisted of waves very much like sound waves. Barkla showed that x-rays have transverse waves like light waves and, indeed, that x-rays and light share several important characteristics.

The basic technique used by Barkla was to use gases to scatter x-rays and to study the resulting secondary radiation to learn more about the x-rays. One of his most important discoveries was that any element that can scatter x-rays produces a characteristic beam of hardness, or penetration. Such characteristic x-rays are of increasing hardness according to their order in the periodic table of elements. Barkla divided the x-rays into two large groups: L radiation (less hardness) and K radiation (more hardness). Henry Moseley was influenced by Barkla's work when he developed the concept of the atomic number of elements.

Barkla learned that the scattering of the x-rays occurs in direct proportion to the density, or molecular weight, of the gas used to do the scattering. Within the gas molecules the electrons, or negatively charged particles of the atoms, are responsible for the scattering. Barkla decided that the more massive atoms contain more charged particles. His work pointed to a connection between the number of charged particles in an atom and the position of the element in the periodic table.

Barkla was born in Widnes, Lancashire, England. He began his studies at the Liverpool Institute. Then he went to University College, Liverpool, from which he graduated in 1898. He also studied at Trinity and King's colleges, Cambridge. In 1902 Barkla joined the faculty at Liverpool. In 1907 he began teaching at the University of London. From there he went to a professorship in physics at King's College, London, in 1909. Next, in 1913, he became professor of natural philosophy at the University of Edinburgh and held that post until his death. During his lifetime he wrote

more than seventy papers on various topics connected with x-rays.

BARTON, DEREK HAROLD RICHARD (1918–)

Derek H. R. Barton, a professor of or-...ic chemistry at London's Imperial ...ege of Science and Technology, ...d the 1969 Nobel Prize in chemistry ... Odd Hassel, a retired Oslo Uni-...y professor. The two scientists were ...d for their research into confor-...n analysis, or the shape of mole-... (*See* Odd Hassel.)

...arton

...le Barton was a visiting professor ...rvard University in 1949-1950, a ...gue expressed confusion over the ...sistent behavior of organic sub-...s. Drawing on his studies in ster-...hemistry, Barton decided that such ...ior probably could be explained ... analysis of the three-dimensional ... of the substance. Although it had ...accepted for a century that mole-...s were three dimensional, chemists ... still treating cyclohexanes as if ...y were two dimensional. Barton and Hassel determined that such hydrocarbon molecules could occur in a variety of positions if the atoms within them were twisted into new configurations.

Their work has had many applications in both medical research and the development of new drugs. For example, the discovery of the double helix of deoxyribonucleic acid (DNA), which carries the genetic code and determines heredity, was made possible through their findings.

Barton was born at Gravesend, England, and attended Tonbridge School and the Imperial College, University of London. He taught at several universities, including Birkbeck College, in London, the Massachusetts Institute of Technology, the University of Wisconsin, the University of Illinois, and the University of Glasgow, in Scotland. He received many honors, including honorary degrees from the University of Montpellier, in France, and the University of Dublin, in Ireland, and he was made a fellow of both the Royal Society, in London, and the Royal Society of Edinburgh.

BASOV, NIKOLAI GENNADIEVICH (1922–)

Throughout history it has happened that scientists in different parts of the world have worked on the same project or goal independently of each other. The wonders of modern communications have lessened the chance of such an occurrence but have not altogether removed it. It becomes difficult in such cases to give exact credit for a discovery. The 1964 Nobel Prize in physics was awarded to Nikolai Gennadievich Basov, A. M. Prokhorov, and Charles H. Townes for their discovery of the maser-laser principle. Basov and Prokhorov were Soviet scientists who worked together at the Lebedev Institute of Physics in Moscow, a research institute of the Academy of Sciences of the U.S.S.R. Townes, then a professor at Columbia University in the United States, worked independently. (*See* Charles Hard Townes; Aleksandr Mikhaylovich Prokhorov.)

The field of quantum electronics was born through the work of these three men. Basically, this is a branch of electronics with the emphasis on quantum mechanics, which, in simple terms, is a mathematical theory dealing with the interaction of radiation and matter in finite, measurable quantities. Lasers and masers, devices produced in the field of quantum electronics, have many scientific and industrial applications. The laser gives out a powerful beam of light that is used in surgery for which known medical instruments are inadequate.

Maser stands for *m*icrowave *a*mplification by *s*timulated *e*mission of *r*adiation. Basov is generally credited with the discovery of the maser principle (but Townes is credited with making the first maser). He looked for, and eventually found, a way to amplify electromagnetic waves by forcing atoms to release the same kind of waves at an increasing rate. The forcing was accomplished by bombarding the maser's atoms with radiant energy. Then secondary waves were created. It became a problem to stimulate these secondary waves in such a way that they duplicated the strength and power of the original incoming waves.

Basov was born in Leningrad. He studied physics at the Moscow Physical Engineering Institute. In 1957 he received the prestigious degree of doctor of physical-mathematical sciences. By this time he had several years' experience at the Lebedev Institute and was appointed deputy director in 1958. While maintaining his post at the Lebedev Institute, he began teaching solid-state physics at the Moscow Physical Engineering Institute in 1963.

A prolific author, Basov published more than 150 works. In 1959 he and Prokhorov received the Lenin Prize for the discovery of the maser principle.

BATESON, WILLIAM (1861–1926)

William Bateson, English biologist and founder of the science of genetics, was born in Whitby, Yorkshire. He was the son of William Henry Bateson, master of St. John's College, Cambridge, and he himself entered Cambridge after attending Rugby. Pursuing his boyhood interest in natural history, he became a student of zoology.

Bateson interrupted his studies at Cambridge and went to Hampton, Virginia, to investigate the *Balanoglossus*, a genus of wormlike marine organisms with a larval stage resembling that of echinoderms, such as starfish. These investigations led to his revolutionary theories concerning the evolution of vertebrates. It was revealed that members of this genus possess a notochord, a stiff rodlike structure running the length of the back. This established them as chordates, which include the vertebrates and, therefore, man, since all vertebrates possess a notochord at some stage of their embryonic development, and was the first indication that chordates are offshoots of a primitive echinoderm stock.

Back at Cambridge, Bateson began the study of variation. His search among the fauna of the salt lakes of western central Asia and northern Egypt for a relationship between local variations of aquatic species and local conditions revealed that variation is discontinuous and not related to conditions of life. These studies culminated in his book *Materials for the Study of Variation* (1894).

In 1900 Bateson recognized the recently rediscovered work of Gregor Johann Mendel by Hugo de Vries (1848–1935), K. E. Correns (1864–1935), and E. von Tschermak (1871–1962) as the key to an understanding of heredity, variation, and evolution. He became a strong supporter of Mendel's principles

that heredity occurs by the transmission of particulate elements, genes, instead of being continuous and nonparticulate. His experiments extended the scope of the principle of segregation of genes, and he was one of the first to show its application to such hereditary diseases in man as hemophilia, albinism, and color blindness. The work of the research group that he had set up at Grantchester, near Cambridge, to study the genetics of plants and animals, such as the inheritance of comb shape in the fowl and the transmission of pollen shape and flower color in the *Emily Henderson* variety of sweet pea, showed that not all characteristics are inherited independently, but that some characteristics are inherited together. This gene linkage was later explained by the American geneticist Thomas Hunt Morgan in his principle that linked genes tend to remain together because they're located on the same chromosome.

William Bateson

Bateson became professor of biology at Cambridge in 1908. Within a year, however, he left to become director of the John Innes Horticulture Institute at Merton, Surrey. There he conducted important and valuable experiments until his death. His other books include *Mendel's Principles of Heredity* (1902) and *Problems of Genetics* (1913).

BEADLE, GEORGE WELLS (1903–)

The distinguished geneticist and educator George Wells Beadle received the 1958 Nobel Prize in medicine or physiology. He shared the prize with Joshua Lederberg and Edward Lawrie Tatum. In the course of his rich and varied career, Beadle served as president of the University of Chicago from 1961 to 1968. (*See* Joshua Lederberg; Edward Lawrie Tatum.)

Beadle was born in Wahoo, Nebraska. He received the bachelor of science and master of science degrees from the University of Nebraska. He earned his doctor of philosophy at Cornell University, Ithaca, New York, in 1931. Then he went to work in the laboratory of Thomas Hunt Morgan at the California Institute of Technology; Morgan was engaged in studying genetics through the medium of the fruit fly (*Drosophila melanogaster*).

George Beadle

After a distinguished career as a geneticist, culminating in the 1958 Nobel Prize in medicine or physiology, George Wells Beadle was elected president of the University of Chicago in 1961 and served in that capacity for seven years, until 1968. The following year he became its William E. Wrather Distinguished Service Professor of Biology.

In 1935 Beadle went to Paris and continued to study the genetic makeup of fruit flies. Working together with Boris Ephrussi, he showed that eye color in the fly is controlled by specific genes.

Returning to the United States in 1936, he taught genetics at Harvard University for a year. In 1937 he was appointed professor of biology at Stanford University, Palo Alto, California, and remained there until 1946; it was at Stanford that he did the basic research that led to the Nobel Prize. From 1946 to 1961 he was professor and chairman of the biology division at the California Institute of Technology.

After leaving the presidency of the University of Chicago in 1968, he became director of the Institute for Biomedical Research of the American Medical Association. In 1969 he was elected to the William E. Wrather Distinguished Service professorship at the University of Chicago.

Beadle and Tatum performed their studies using the medium of mold (*Neuspora crassa*). They had found that fruit flies were not suitable for the kind of biochemical research they wanted to do. By adding various compounds and applying x-rays to the mold, they discovered that they could induce various growths as mutations. They were then able to study the chemical action in the genes as they produced the mutation and afterward. Beadle arrived at the conclusion that each gene produced one specific enzyme, not more. This basic research, concluding that the function of genes is to synthesize enzymes (including protein), opened a field of new inquiries in genetics.

Before Beadle the focus of genetics was on the physical characteristics produced by the gene. With the work of Beadle, Lederberg, and others the focus began to shift to chemical studies of the gene itself and how it produces the vital enzymes.

In addition to the Nobel Prize Beadle received more than a dozen honorary degrees from colleges and universities, including Oxford, and, in 1960, the Lasker Award for medical research. He was also elected to numerous honorary societies, including the National Academy of Sciences, the American Association for the Advancement of Science, and the Royal Society of London. Of his several books, the definitive one is probably *The Language of Life,* which he coauthored with his wife, Muriel.

BEAUMONT, WILLIAM (1785–1853)

William Beaumont, a U.S. surgeon and physiologist known for his research on the chemical nature of digestion, was born in Lebanon, Connecticut, the son of a farmer. He became a teacher in Champlain, New York, but after three years he began studying medicine with a practitioner in St. Albans, Vermont. He obtained a license to practice and during the War of 1812 served as surgeon's mate in the U.S. Army. After the war, he practiced in Plattsburgh, New York, but later rejoined the army and was sent as surgeon to Fort Mackinac in northern Michigan. He also served at other stations, notably St. Louis (1834–1839). Upon leaving the army Beaumont entered private practice in St. Louis, becoming professor of surgery at St. Louis University in 1837. He remained there for the remainder of his life.

It was while Beaumont was stationed at Fort Mackinac that an accident occurred that had a profound effect on his work. On June 6, 1822, Alexis St. Martin

(1804?–1880), a Canadian trapper, was accidentally shot at close range. A charge of duck shot entered his left side from behind, leaving a small but permanent opening, or fistula, into his stomach. Beaumont tended St. Martin and saw the opportunity to study the digestive processes directly.

Through the opening, Beaumont was able to observe the changes going on in St. Martin's stomach at varying times and under different conditions and to extract gastric juice for analysis. Altogether, he conducted 238 experiments intermittently from May 1825 to November 1833. By means of these experiments, Beaumont established the chemical nature of digestion, observed the comparative rates of dissolution of foods, and noted the effect of the emotions on gastric secretion.

William Beaumont

Through a permanent opening into the stomach of a Canadian trapper—the result of a shooting accident—William Beaumont could observe the digestive processes directly and obtain gastric juice for analysis.

A preliminary account of these experiments was published in 1825. His classic *Experiments and Observations on the Gastric Juice and the Physiology of Digestion* appeared eight years later. The work was immediately and widely acclaimed in scientific circles.

BECQUEREL, ANTOINE HENRI
(1852–1908)

A spell of bad weather in the late winter of 1896 opened the way to one of the most significant of scientific events—the discovery of natural radioactivity. Antoine Henri Becquerel shared a Nobel Prize in physics for the work he pursued after that cloudy week in Paris, France.

Becquerel's grandfather, Antoine César Becquerel, helped found electrochemistry, and Becquerel's father, Alexandre Edmond Becquerel, studied the effects and character of electric light, solar radiation, and the phenomena of phosphorescence. The Becquerels were traditionally interested in the radiations emitted by fluorescent substances.

Antoine Henri Becquerel was intrigued by the discovery of the German scientist William Roentgen of rays similar to light rays but capable of penetrating opaque substances and affecting photographic plates. These radiations had never been observed in nature. They did not seem to exist in the solar spectrum, nor were they contained in the light from any known luminous source. Becquerel wondered if some substance that had fluorescent properties might not be stimulated to emit the rays.

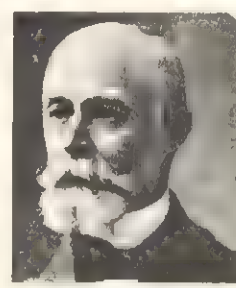
Becquerel decided to test all the substances that appeared to be fluorescent. His method was to expose a sample of the substance to sunlight and then to place it in contact with a photographic plate wrapped in lightproof paper. Between the sample and the plate, he inserted a metal object to ensure that the radiations were of the Roentgen, or x-ray, type, capable of passing through a thin layer of metal. When the plates were developed, they showed fogging. This, Becquerel decided, was an indication that fluorescence produced x-rays.

On February 26, 1896, Becquerel once again wrapped photographic film in black paper and placed upon it a crystal of fluorescent chemical in which his father had been interested—potassium uranyl sulfate, a uranium ore. He waited and waited to expose the apparatus, but the sun did not come out. On March 1 he decided to develop the plates anyway. He thought that perhaps the delay had deteriorated the emulsion. When he developed the plates, he was astonished to find that they had received strong impressions despite the fact that they had not been exposed to the sun. He saw that rays from a uranium ore affected a photographic plate in the same way that x-rays do. The rays obviously were not related to any external source of energy, nor was fluorescence involved.

Although Becquerel happened upon nuclear radiation by chance, his subsequent research gave the first clear indication that atoms have an internal structure, the atomic nucleus. In 1901 he identified the electrons radiated by uranium atoms as the radioactive part of the compound. Becquerel invented the first instrument for detecting nuclear radiation. This hastened the discovery of polonium and radium by Pierre and Marie Curie, with whom he shared the 1903 Nobel Prize in physics. (*See* Pierre and Marie Curie.)

As a young engineering student at the École Polytechnique, Becquerel began his studies in physics, which in 1875 earned him a post there as assistant lecturer. In 1878 he became assistant naturalist in the laboratory of the Museum of Natural History, and in 1892 he suc-

Antoine Becquerel



The Maison Cuvier was the scene of one of the most important scientific events of the nineteenth century—Antoine Henri Becquerel's discovery of radioactivity in 1896. For this achievement the French physicist shared a Nobel Prize with Marie and Pierre Curie.

ceeded his father as professor at the museum. From 1895 until 1908 Becquerel was professor at the École Polytechnique.

His early scientific research dealt with magnetic rotation of the plane of polarization of light, with the influence of the Earth's magnetism, and with absorption of light by crystals. These studies, however, were overshadowed by those in radioactivity, for which Becquerel received awards and honors from all over the world. For some time, radiation from uranium was called Becquerel rays.

BEEBE, CHARLES WILLIAM (1877–1962)

The first man to scout the ocean depths was Charles William Beebe, a versatile U.S. biologist, explorer, and author. In 1934 near Bermuda, he descended in a steel sphere to a depth of 3,028 feet, setting a record for many years.

Beebe was born in Brooklyn, New York, and studied at Columbia University. Early in his career he became curator of ornithology at the Bronx Zoological Park in New York City. There he built a fine collection of live birds. In 1918 he was named director of the Department of Tropical Research of the New York Zoological Society. In 1945 he established a tropical research station on Trinidad for the department and took part in its activities until his death.

His broad interests in animal life spurred Beebe to lead scientific expeditions to, among other places, Nova Scotia, Mexico, South America, the Himalayas, and Borneo. He became a diver when he took part in early underwater explorations, but he was frustrated by having to stop at about forty feet beneath the surface. He wanted better equipment for studying and hunting sea animals. In collaboration with Otis Barton, a U.S. engineer, he designed the bathysphere—"sphere of the deep." The two men first took it down into tropical waters in 1930.

The bathysphere was about 4½ feet in diameter and weighed more than 2 tons. Its walls were about 1½ inches thick. The door, which weighed about 550 pounds, was not much more than a foot in diameter. Three windows made of cylinders of fused quartz were 3 inches thick and about 8½ inches in diameter. Quartz was chosen because of its strength and its transparency to all wavelengths. Fixed to the inside walls were cylinders of oxygen and vessels of hydrate of calcium to eliminate carbon dioxide and of calcium chloride to absorb humidity. There also were fans, powerful searchlights, and a telephone connected to the surface. A steel cable about 3,600 feet long was used to lower the sphere into the sea.

Beebe's party included scientists, technicians, and sailors. On June 6, after a trial descent with the bathysphere empty, Beebe and Barton descended to 800 feet. On subsequent dives they saw iridescent fish, great masses of crustaceans, and, at 1,250 feet—after a zone of no apparent life—shrimps of an unknown species.

Studying optical phenomena with a spectroscope, they discovered that red disappeared at a depth of 49 feet; yellow, at about 100 feet farther down; and blue, at about 330 feet; at 460 feet, only violet remained. At 820 feet, a faded grayish line was visible with the spectroscope, while the naked eye perceived [illegible] faint bluish light.

Beebe undertook a new series [illegible]f descents in 1934. On August 11 [illegible] and Barton made the first dive, rea[illegible]ing a depth of 2,500 feet and finding [illegible]nown species of sea life. Four days [illegible] they reached their record depth of [illegible] feet. At that depth, Beebe was int[illegible]d by the jets of luminous fluid that so[illegible] organisms used for defense and als[illegible]y the fact that the bright searchlig[illegible] never seemed to attract the deep-sea c[illegible]tures.

This expedition brought to a[illegible] end a series of explorations quite [illegible]ortant to science. With engaging hum[illegible] Beebe later said that "not finding a ph[illegible]se solemn enough to echo down the ce[illegible]uries," he had entered the bathysphere [illegible]ithout saying a word.

Beebe received many hon[illegible]rs and prizes for scientific research an[illegible]writing. Among his books, which have [illegible]en extremely popular, are *Monogra[illegible] of the Pheasants* (1918), *Jungle Da[illegible]* [illegible]1925), *Beneath Tropic Seas* (1928) [illegible]*ook of Naturalists* (1944), *High Jung[illegible]* [illegible]1949), and *Unseen Life of New York* [illegible]53).

In August 1934 Charles William Beebe and his colleague Otis Barton were lowered in a bathysphere into Bermuda waters and descended to their record depth of 3,028 feet.

Charles Beebe

BEHRING, EMIL ADOLF VON (1854–1917)

The first Nobel Prize in me[illegible]ne or physiology was awarded to the [illegible]erman bacteriologist Emil Adolf von Beh[illegible]ng in 1901. Behring is considered the fat[illegible]er of immunology for his development of both tetanus and diphtheria vaccines.

Behring was born in Hansdorf, West Prussia. After taking his medical degree at Berlin, he entered the army medical corps. In 1889 he began work as an assistant at Robert Koch's Institute for Infectious Diseases in Berlin.

In 1890, working with the Japanese scientist Shibasaburo Kitasato, he demonstrated that it was possible to vaccinate an animal against tetanus, or lockjaw, by using serum from the blood of an animal that had previously been infected with tetanus. The German scientist Paul Ehrlich also helped develop this breakthrough.

Behring also discovered how to immunize against diphtheria. He used serum from an animal in which living cultures of diphtheria bacillus had been planted. Because diphtheria was a great killer disease at that time, the discovery of an effective vaccine was widely heralded. In 1891, in Berlin, it was first used on a human.

Turning to teaching, Behring became a professor at Halle University in 1894 and at Marburg University in 1895 (both in Germany). For developing the diphtheria antitoxin, he received large monetary prizes from the Paris Academy of Medicine and the Institute of France.

BÉKÉSY, GEORG VON (1899–)

[illegible] first physicist to be awarded the Nobel Prize in medicine or physiology w[illegible]eorg von Békésy. He won the [illegible] 1961 for his discoveries conce[illegible] the mechanism of hearing.

[illegible] in the inner ear there is a spiral t[illegible]alled the cochlea, in which hearin[illegible]es place. The cochlea is divided b[illegible]silar membrane containing thousa[illegible]f tiny fibers. A previous theory ab[illegible]earing held that the fibers themsel[illegible]vibrated and received correspondin[illegible]rations from sound waves. Békésy sh[illegible] that this was incorrect and that ac[illegible] sound waves flow through the flu[illegible] the cochlea and simply vibrate of[illegible] basilar membrane. He demonst[illegible] how the process is affected by dif[illegible]nces in the loudness or pitch of va[illegible] sounds.

[illegible] Békésy, scientists generally th[illegible]t that the ear changed drastically ri[illegible]fter death and that therefore it [illegible]possible to study the inside of [illegible]ar. Békésy succeeded in study[illegible]uman ear and proved that the [illegible]d not deteriorate rapidly after [illegible]

[illegible]n audiometer to test hear[illegible]rk made it possible to dis[illegible]etween various forms of deafn[illegible] to treat them more competently. [illegible]ral, Békésy was very resource[illegible] methods and in his instrumentat[illegible] When he could not find a way to [illegible]mulate a nerve source properly in the [illegible]nstruction of a model of the cochlea, he decided to use his own arm held up next to the model. In this way he was able to feel vibrations at appropriate points in his experiments.

Békésy was born in Budapest, Hungary. He received a chemistry degree at Bern, Switzerland, in 1920 and a doctorate in physics at Budapest in 1923, as well as honorary medical degrees for his work on the ear.

For more than twenty years Békésy worked for the Hungarian telephone system. That is how he developed his competence with instruments. His research on the ear began as early as 1928. While working for the telephone system, he also served as professor of physics at the University of Budapest, from 1939 to 1946. He left Hungary for Sweden and worked for a short time at the Royal Institute of Technology in Stockholm. In 1947 he emigrated to the United States and took a position with the psychoacoustical laboratory at Harvard University.


Georg von Békésy

BELL, ALEXANDER GRAHAM (1847–1922)

Once, not so long ago, the only means of communicating with people at a distance was the mail service or a messenger, with all the slowness and hazards that such methods involved. That relatively simple instrument the telephone, which has revolutionized many aspects of our lives and has become almost an extension of our auditory system, had not yet been invented.

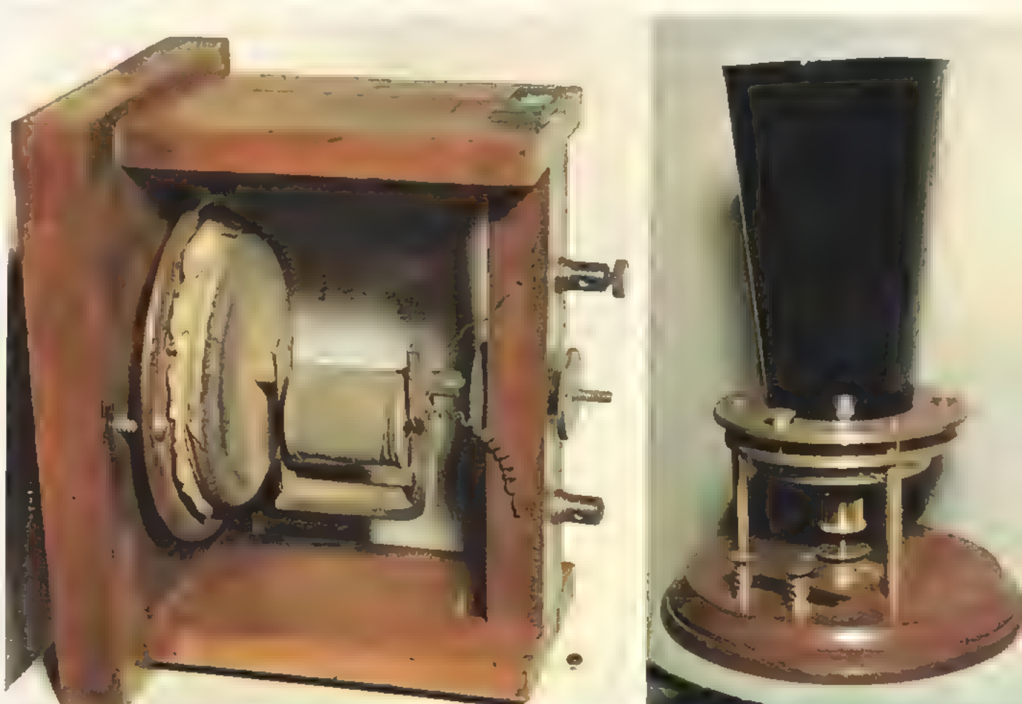
Then one day a teacher of the deaf, Alexander Graham Bell, tried to construct an instrument that could receive and transmit sound. His experiments led him to the invention of the telephone. Before long its advantages, which at first had not been appreciated, led to its worldwide diffusion. Today a huge company that builds and operates telephones and telecommunication systems, one of the largest concerns in the world, is named after the inventor.

Alexander Graham Bell was born in Edinburgh, Scotland. He was the son of Alexander Melville Bell, a teacher of the deaf and an expert on auditory problems, who was to become renowned in his own right by his system of "visible speech"—the representation of human sounds by symbols. After attending Edinburgh University, the younger Bell also became a teacher but then took up the study of medicine at University College, London.

Meanwhile, his health had been of serious concern to his father, who, thinking that the Edinburgh climate was unhealthful for a young man who showed consumptive tendencies, decided to emigrate to Canada. In 1870, therefore, what was left of the Bell family left Europe


Alexander Graham Bell

Compared with the modern telephone and telegraph, Alexander Graham Bell's telephone and transmitter were strange and rudimentary machines.



for the American continent. After a brief period in Canada, Alexander Graham settled in Boston.

On the strength of his education and the experience that he had gained through his father, Bell, in 1872, opened a school for the training of teachers of the deaf. The following year he became a professor of vocal physiology at Boston University. This gave him the opportunity to experiment with the mechanical production of sound, which had interested him since his university days.

One of these experiments led to the musical telegraph, an instrument that, though rudimentary, could transmit musical notes over a distance. The possibility of such an apparatus had occurred to Bell when he noticed that a tuning fork can be made to vibrate by means of an electromagnet. Bearing this in mind, he constructed a battery of electromagnets, which, when properly controlled from a distance by electric wires, could produce a kind of harmony by inducing vibrations in a number of tuning forks.

A musical note can be reproduced with a tuning fork, but how can the human voice, with all its modulations, be reproduced? Bell had various ideas, but he had spent all his savings on the experiments for the musical telegraph.

In the meantime, however, he had become engaged to one of his deaf students, Mabel Hubbard; and her father, Gardiner Hubbard, offered to finance his experiments. This allowed him to continue his research on the transmission of sound by electricity. The experiments were not easy—it was only after much effort that he succeeded in transforming sound impulses into electric impulses and vice versa—but they finally led to the invention of the microphone.

By 1875 the microphone had been perfected to a point where it could emit pleasant sounds when properly excited. One day the following year, Bell spilled battery juice on his clothes while experimenting with a telephone model. Being exposed to the danger of burns, he automatically cried out to his assistant, Thomas Watson (1854–1934), "Watson, please come here. I want you." Watson, who was at the other end of the circuit in another room, heard the message transmitted by the telephone microphone and came running. It was the first telephonic communication. The telephone was now a reality.

On the advice of his future father-in-law, Bell decided to present his invention at the Centennial Exposition in Philadelphia. The telephone aroused little interest until the visiting emperor of Brazil, Pedor II, made headlines by exclaiming, "It talks!" after hearing Bell's voice on it reciting Hamlet's famous soliloquy. From that moment it became the great attraction of the exhibition, even if only as a curiosity.

Bell lost no time, however, in launching his invention commercially, but this proved very difficult. The idea of such an instrument had also occurred to other inventors, who, in turn, had produced similar appliances. In a short time, Bell had to fight hundreds of priority cases, all of which he won. He even had to contend with the Western Union Telegraph Company, behind whose invention loomed no less a figure than Thomas Edison.

Even after the telephone, Bell had no wish to abandon research. He experimented with many diverse things, such as mechanical flight, animal breeding, and air conditioning. He even invented a metal-locating device that was used in trying to locate the bullet in the body of the dying U.S. President James A. Garfield. The device didn't work in this case because no one thought of removing the steel-springed mattress, which was interfering with the search. Bell's most useful studies, however, were still those relating to acoustics. He improved on Edison's phonograph and invented the photophone, which transmitted sound by vibrations in a beam of light. This was an achievement that anticipated the transmission of telephonic and television signals by means of a laser light beam.

In addition, Bell founded the journal *Science*, the American Association to Promote the Teaching of Speech to the Deaf, and the Volta Bureau for the increase of knowledge relating to the deaf. He also served as president of the National Geographic Society and as a regent of the Smithsonian Institution.

Bell was considered one of the greatest living inventors and received many honors. He was Hughes Medallist of the Royal Society. In 1915 he was invited to the inauguration of the first transcontinental North American telephone line. Bell, in the East, once again spoke to his old assistant, Watson, who was now in the Far West: "Watson, please come here. I want you." Now, however, forty years later, these words spanned a whole continent, not just a few rooms. When Bell died on August 2, 1922, all telephones in the United States were silenced for one minute as a sign of national mourning. In 1950 he was elected to the Hall of Fame for Great Americans, which is located in New York City.

BERGIUS, FRIEDRICH (1884–1949)

In 1931 the Nobel Prize in chemistry was awarded to the German chemist Friedrich Bergius for his work in developing industrial chemical processes utilizing the effects of high pressure on chemical reactions. Bergius shared the Nobel Prize with Karl Bosch (*See* Karl Bosch.)

Bergius, whose father was the head of a chemical factory, was born near Breslau at Goldschmieden, Germany. He was educated at the universities of Breslau, Leipzig, and Berlin and also attended technical schools in Karlsruhe and Hanover. Bergius studied with Walther Nernst and Fritz Haber, earning his doctorate in 1907.

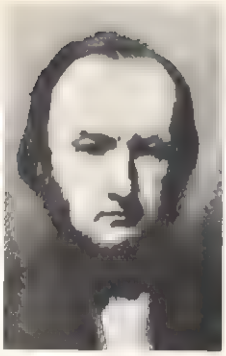
He founded a private technical research laboratory in Hanover and there investigated the effects of high pressure on chemical reactions. In [illegible] he first succeeded in developing a method for making gasoline from coal and heavy oil that had been treated with hydrogen and subjected to high pressure at high temperatures.

In 1914 Bergius became the head of a research laboratory at the Goldschmidt Company in Essen. There he worked on transforming his earlier laboratory discovery into a commercial chemical process. In 1925 he sold his patent rights on the fuel-oil process to the Badische-Anilin-und Sodafabrik in Ludwigshafen. He then turned his attention to experiments involving the hydrolysis of wood cellulose through treatment with hydrochloric acid. Eventually he invented a process for producing alcohol and sugar from wood.

During World War II, Bergius' processes were used in Germany to supply gasoline and to make some edible products out of wood. At the end of the war Bergius chose not to remain in Germany. He moved first to Austria, then to Spain, and finally to Argentina. There he became a technical adviser to the Argentine government. He lived in Argentina approximately only one year, however, before his death in Buenos Aires.

BERNARD, CLAUDE (1813–1878)

The French physiologist and founder of experimental medicine Claude Bernard made important discoveries regarding digestion. He was born in the village of Saint-Julien, near Villefranche, in the *département* of Rhône. After an early schooling by the Jesuits in Villefranche, he continued his education in Thoissey, Ain. To further his studies, he enrolled



Claude Bernard

i[illegible] college in Lyons, but, thinking [illegible]anted to be a writer, he soon [illegible] work for a druggist in order to [illegible]ving while devoting himself to [illegible] Encouraged by the success of [illegible]edy *La Rose du Rhône*, he wrote a [illegible]act play, *Arthur de Bretagne*, w[illegible] together with an introduction to the [illegible] Saint-Marc Girardin, he took t[illegible] to seek his fortune when he was t[illegible]ne.

[illegible]hn, however, suggested that Bern[illegible] study medicine instead of beco[illegible] a playwright. Heeding this advi[illegible] Bernard entered the School of M[illegible] in Paris in 1834. He became an as[illegible] to the French physiologist Fr[illegible] Magendie at the Collège de [illegible] 1841 and two years later ob[illegible] medical degree. He thereupon de[illegible] himself entirely to physiology.

[illegible] Bernard was appointed to the ne[illegible]created chair of experimental ph[illegible] at the Sorbonne. The following [illegible] he succeeded Magendie as profess[illegible] experimental medicine at the Co[illegible] de France. Then in 1868 he beca[illegible] professor at the National Museum [illegible] Natural History, in the Jardin des Plantes, Paris.

Many honors came to Bernard for his work relating to physiology. The Académie des Sciences awarded him its grand prize three times, and in 1854 he became a member of the Académie. He was also elected to the Académie de Médecine, the Royal Society of London, and the Académie Française. When Bernard died, he was given a public funeral. This was the first time that a scientist was so honored in France.

Bernard's major contributions to the science of physiology were his discoveries regarding digestion and the vasomotor system. To help him in the study of the digestive processes, Bernard created artificial openings in animals—a method that had been suggested to him by the experiments of the U.S. surgeon and physiologist William Beaumont. For this, Bernard was criticized by the antivivisectionists of the day, and his wife managed to obtain a legal separation.

By his studies and experiments, Bernard concluded that although digestion starts in the stomach, most of it takes place in the small intestine and is further aided by the pancreatic juice, which breaks down fat molecules and also changes starch into maltose. Bernard reached these conclusions when he noted that the lacteals in the mesentery of a meat-fed rabbit bore evidence that the fat of the meat had been digested, indicated by the presence of a white fluid, but only below the entrance of the pancreatic duct to the duodenum. To Bernard, this showed that the fat had been acted upon by the pancreatic juice, which had started to flow when stimulated to do so by the passage of the acid stomach contents into the duodenum.

Perhaps Bernard's most famous discovery was that of the presence of a starchlike substance in the mammalian liver. Bernard isolated this substance and called it glycogen. Upon finding glucose in the hepatic vein and in the liver tissue of an animal on a sugar-free diet, even twenty-four hours after the liver had been washed free from sugar, Bernard concluded that some sugar-forming substance in the liver had been changed to sugar. He proceeded to show that glycogen consists of blood sugar and acts as a reserve store of carbohydrates, which can be broken down again to sugar when necessary. Thus, the sugar content of the blood is maintained at a steady level. This also proved that the body can build up complex chemicals (anabolism), as well as tear them down (catabolism). Earlier he had demonstrated that puncturing the fourth ventricle of the brain causes sugar to appear in the urine, an indication that sugar production in the liver is controlled by the nervous system.

Bernard's discovery of the glycogenic function of the liver extended his theory of the internal environment to chemical reactions, as well as to physical ones. According to this theory, the body mechanisms strive to maintain a constant inner environment despite the outer changing one. The maintenance of this constant internal environment indicates that the various organs are under an integrated central control. This theory is generally accepted now; but when it was first advanced by Bernard in the 1850s, it was contrary to the trend of thought at the time that organs function in relative isolation.

Besides his important discoveries relating to digestion, Bernard also discovered the vasomotor system and its effect on blood flow. He noticed that cutting the cervical sympathetic caused an increase of temperature and, therefore, more active circulation and more forcible pulsation of the arteries in certain parts of the head. Electric stimulation of the upper portion of the divided nerve had the opposite effect. The existence of both vasodilator and vasoconstrictor nerves was thereby established.

Bernard also investigated the physiological action of such poisons as carbon monoxide and curare, the South American arrow poison. His studies revealed that the ability of carbon monoxide to displace oxygen in its combination with hemoglobin causes death by oxygen starvation because the body cannot counter this displacement fast enough. While engaged in these studies, Bernard reached the conclusion that the respiratory function of the blood is carried out by the erythrocytes and that oxygen, instead of being in solution, is bound to some substance in the erythrocyte. It was the German biochemist Ernst Felix Immanuel Hoppe-Seyler who discovered this substance and named it hemoglobin. After several years of experiments with curare, Bernard concluded that it poisons the nerve endings of muscles throughout the body.

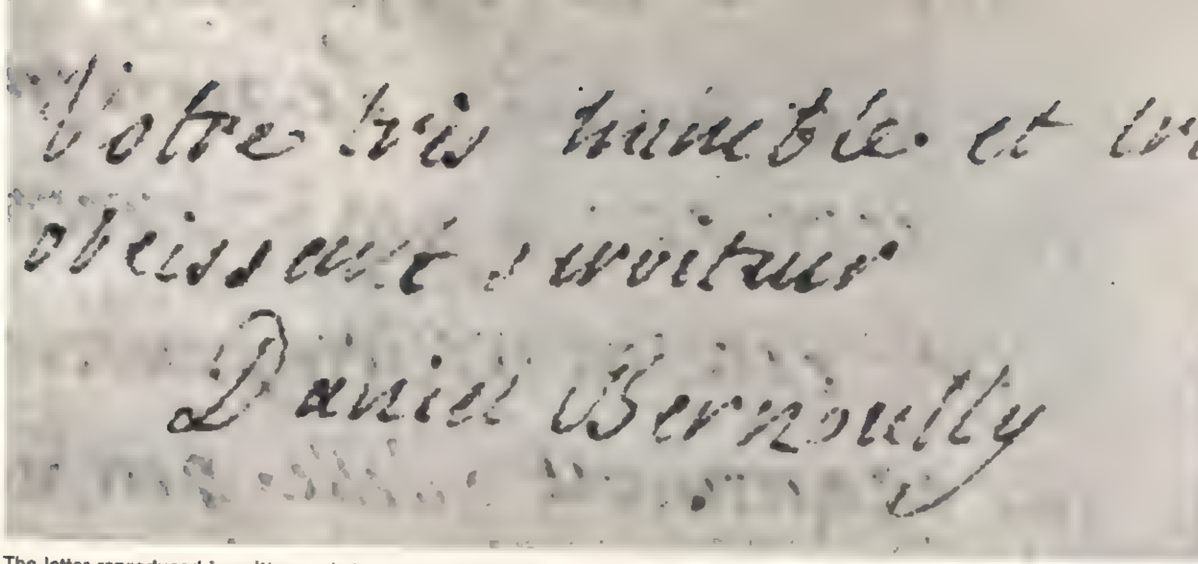
Bernard's written works include *Introduction à la médecine expérimentale* (1865), *Physiologie générale* (1872), and seventeen volumes of lectures.

BERNOULLI FAMILY

For more than a century the Bernoulli family of Switzerland produced brilliant sons who explored and developed new fields of mathematics. Moreover, at least 120 descendants of the remarkable family distinguished themselves in professions apart from mathematics.

In each generation between the mid-seventeenth century and the late eighteenth, the younger Bernoullis turned to careers in mathematics and science after their elders prepared them for other professions. During this period, the many significant Bernoulli contributions to knowledge included development of the infinitesimal calculus in about its present-day form and the formulation of the kinetic theory of fluids.

In 1583 the Catholics of Antwerp, Belgium, began to persecute Huguenots. Among those who left the city were members of a merchant family named Bernoulli. They took refuge first in Frankfurt, Germany, and later in Basel, Switzerland. The distinction of the highly in-


Votre très humble et trè
obeissant serviteur
Daniel Bernoully

The letter reproduced is written and signed by Daniel Bernoulli, distinguished eighteenth-century mathematician and physicist, whose outstanding work was in hydrodynamics. Three generations of Bernoullis made si ant contributions to the field of mathem

telligent Bernoullis was in the field of commerce until the mid-1600s, when the spark of scientific genius first appeared in Jakob I (1654–1705).

Jakob studied theology, but he refused a church appointment after completing his education. At the age of thirty-three, after gaining recognition as a lecturer in experimental physics, he became professor of mathematics at the University of Basel. There he continued his studies until his death. In his research, Jakob discovered the basic material on the integral and differential calculus as it had been developed in rough form by Sir Isaac Newton and Gottfried Leibniz. With this base, he mastered the concept of the derivative and integral and applied these methods to various problems. His studies related mainly to the perfecting of Pierre de Fermat's theory of maxima and minima. As presented by Jakob, this is now known as the theory of variations.

Jakob examined a wide variety of curves, including the lemniscate and the logarithmic spiral—studies in which he used the equivalent of polar coordinates. He also determined the catenary—the curve of a hanging chain—and the isochrone—the curve along which an object falls with uniform vertical velocity. In his later years, he wrote a paper on infinite series and their summation—a mathematical sequence known as the Bernoulli numbers.

His younger brother Johann (1667–1748) became fascinated by the new mathematical calculus after he was educated in medicine. He became a professor of mathematics at Groningen, Holland, and he succeeded Jakob at Basel upon the latter's death in 1705. Johann was an indefatigable pioneer in optics, physics, chemistry, and economics. Later in life he worked mainly on the principles of mechanics. The two Bernoulli brothers attacked many of the same problems—a circumstance that resulted in professional jealousy and bitter public accusations of plagiarism.

Jakob had no sons, but Johann's three sons and a nephew carried on the tradition of pursuing mathematics after studying for other fields. A nephew and pupil of Jakob and Johann, Nikolaus Bernoulli (1687–1759) first studied law and then turned to mathematics. He became a professor in Padua, Italy. His works deal with infinite series and probability. He returned to Basel to become professor of logic and, later, of jurisprudence.

Johann's eldest son, Nikolaus (1695–1726), studied law and later taught it in Bern, Switzerland. In order to devote himself to mathematics, his real interest, he accepted a post at the Russian Academy in St. Petersburg. He died shortly thereafter.

Johann's second son, Daniel (1700–1782), was possibly the most distinguished member of the Bernoulli line. He left the practice of medicine for mathematics. His main achievement was the discovery of a law now known as Bernoulli's principle: as the velocity of fluid flow increases, its pressure decreases. Daniel was the first scientist to attempt an explanation of the behavior of gases with changing pressure and temperature. His studies of hydrodynamics and of such phenomena as the tides and the motion of vibrating strings were early examples of the science of mathematical physics. Daniel was awarded ten prizes by the French Academy of Sciences.

Johann II (1710–1790), the younger brother of Nikolaus and Daniel, studied law and became a professor of legal rhetoric at Basel University. Be e long, though, he followed in the f steps of his father and brothers. Ev ally he became his father's successor he chair of mathematics as Basel. He n three prizes awarded by the Frenc cademy of Sciences.

Two of his sons, Johann (1744–1807) and Jakob II (1759– were, in their turn, eminent math ticians. True to the family tradition, h were educated for other work. Joha II, who studied law and philosophy, b me director of the Berlin Observato where he undertook advanced studies physics and mathematics. After emba g on a law career, Jakob II also turne mathematics and physics. With his eath at the age of thirty, the family's mathematical genius waned; but the Bernoullis' studies endure as foundations for present-day scientific progress.

BERZELIUS, JÖNS JACOB (1779–1848)

On his wedding day in 1835, the fifty-six-year-old Jöns Jacob Berzelius, one of the world's leading chemists at that time, was made a baron by the Swedish king, Charles XIV, in appreciation of his many contributions to chemistry. Notable among these were his development of the modern system of chemical symbols, his determinations of atomic weights, and his isolation of many of the elements for the first time.

Jöns Jacob Berzelius was born near Linköping, Sweden, the son of a clergyman and teacher. Following the scientific bent of his mind, he entered the University of Uppsala in 1796 to study medicine, the only university course at that time that could appeal to someone interested in science. He was at once attracted by experimental chemistry and

went to great lengths to conduct his own experiments, even making tremendous s[illegible] to rent a small apartment with a k[illegible]hen, where, on the charcoal stove, h[illegible]ld perform experiments to his heart's content.

Af[illegible] six years at the university, he grad[illegible]ted with a medical degree. In 180[illegible] he became professor of medicine an[illegible]rmacy at what is now the Royal C[illegible] Institute in Stockholm. The [illegible]wedish Academy of Sciences e[illegible] him a member in 1808, and in 18[illegible] resigned his professorship to de[illegible]self to the academy in his posi[illegible]ecretary, which he had been ap[illegible] in 1818.

Jon[illegible]ob B[illegible]

Sa[illegible] vanadium compounds that were par[illegible] large collection belonging to Jöns Jac[illegible]elius are preserved in the museum of th[illegible]dish Academy of Sciences.

While at Uppsala, Berzelius had become interested in the therapeutic effects of galvinism, which led to a lifelong interest in electrochemistry. Thus, when news arrived that an Italian physicist, Alessandro Volta, had discovered a way of obtaining a continuous electric current—the perfect instrument for carrying out experiments in electrochemistry—Berzelius was overcome with enthusiasm. With his friend Wilhelm Hisinger (1766–1852), a Swedish mineralogist, he performed a number of experiments on the splitting of compounds by means of electric currents.

It was from these experiments that Berzelius formulated his famous electrochemical, or dualistic, theory. According to this, the atoms of elements are electrically polarized, and all compounds are divisible into positive and negative parts.

The decade 1810–1820 was the most productive in his life. Berzelius was a great organizer, and he applied this gift to the task at hand. Above all, he had no patience with the chaotic system of chemical nomenclature that was still in use. Although chemistry had by then come a long way from the days of alchemy, many of the symbols used had been inherited from the alchemists. The elements were indicated by symbols similar to those used for the planets. At the time of Berzelius, however, there were only seven known planets, while the number of known chemical elements already ran into the dozens. Apart from this, it often happened that when a chemist discovered a new compound, or even simply found out what it was made of, he felt obliged to invent a new symbol. The terminology of chemistry, therefore, had become more complicated than the Chinese alphabet. To simplify matters, Berzelius suggested that each element should be indicated by the capital initial letter of its Latin name (or the initial plus a lower-cased second letter from the body of the name) and a small numeral subscript (to show the number of atoms of each element present in compounds containing more than one atom of a given element). This new system was adopted and is still in use today.

Beginning in about 1807, Berzelius, pursuing his interest in chemical proportions and sensing the fundamental importance of determining them, began a systematic study of combining weights. By 1818, after many hundreds of analyses of simple and compound bodies, he was able to publish a table of combining proportions and atomic weights that was remarkable for its accuracy. This was still further improved by a second table a few years later. In arriving at his results, Berzelius had used oxygen as the basis of reference for the atomic weights of other substances.

A visit to his laboratory in 1813 by an English physicist who gave him some of the less rare specimens in a collection he had made for the British Museum stimulated Berzelius to investigate the study of mineralogy. Finding the system then in use of classifying minerals according to their physical properties totally inadequate, he worked out an essentially chemical classification, which he made public in 1814. This was based on the observation that silicon is a component common to a great number of minerals.

His interest in mineralogy led to one of his other great contributions to chemistry; namely, his isolation of many of the elements for the first time. Among these were selenium, silicon, and thorium.

Many chemical terms that are commonly used today were first suggested by Berzelius. He introduced the word *halogen*, referred to *catalytic action* and *isomerism*, gave *protein* its name, and used the term *allotropy* to indicate the existence of a substance in different forms.

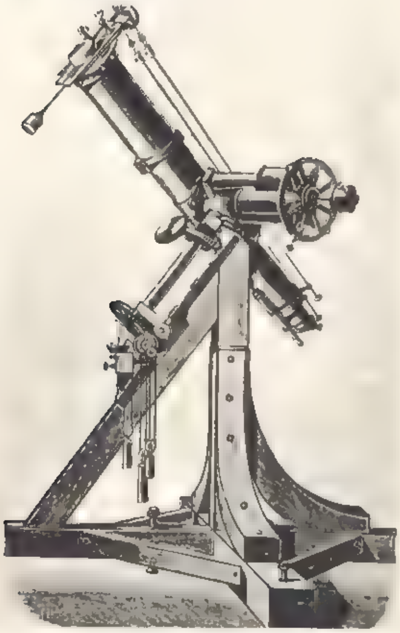
As Berzelius acquired new interests, he did not give up his old ones. He remained a copious writer. In addition to more than 250 monographs and papers, he published *Lehrbuch der Chemie* (1808), which went through five editions and was translated into the principal European languages. At the insistence of the Royal Swedish Academy of Sciences, he also prepared a critical annual report on the progress of physics and chemistry, the *Jahresbericht* (1821–1847).

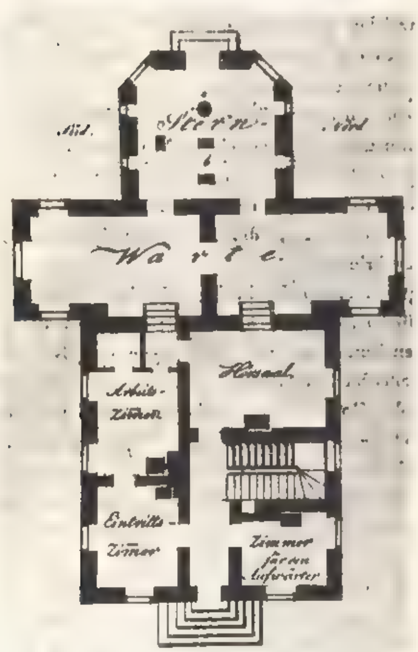
BESSEL, FRIEDRICH WILHELM
(1784–1846)

The self-taught German astronomer and mathematician Friedrich Wilhelm Bessel was the founder of modern precision astronomy. Bessel's interest in mathematics, physics, and astronomy was so intense that he was able at the age of twenty to recalculate the orbit of Halley's comet.

In 1838 he made the first authentic measurement of the distance between the Earth and a specific star. He found that the star known as 61 Cygni is about thirty-five trillion miles away—about six light-years from the Earth. The astronomical term *light-years*, referring to the distance traveled by light in the course of one year, was introduced into astronomy at that time. Bessel also made calculations that led to the discovery of

Friedrich Bessel





For the observatory that he founded at Königsberg in 1810 at the request of Frederick William III of Prussia, Friedrich Wilhelm Bessel ordered a number of precision instruments. He helped design many of these, including the heliometer, as well as the building.

Procyon, a companion star to Sirius.

Bessel, who was born at Menden, near Hanover, Germany, was one of a large family of modest means. He left school at the age of fifteen in order to earn a living. He took a job as an accountant in a Bremen office; but wishing to better himself, he began to study widely on his own. Soon he was aware of his bent for astronomy.

He sent his calculations concerning Halley's comet to Heinrich Olbers, an astronomer who had Bessel's work published and recommended him to the director of an observatory at Lilienthal, Germany. There Bessel acquired his training in practical astronomy. Bessel stayed at Lilienthal until 1810, the year in which Frederick William III, the king of Prussia, ordered him to found an observatory at Königsberg. Bessel was then only twenty-six.

He began his administrative career by ordering a number of precision instruments, many of which he helped design. Bessel wrote years later that there is no instrument that measures up to the astronomer's mathematical ideal; therefore, in order to use an instrument properly, the astronomer must foresee and calculate errors and supply corrections. Bessel made such work easier for all astronomers by publishing, in 1830, his *Tabulae Regiomontanae,* which is still standard.

Although his principal contributions were in astronomy, the refinements that he introduced in mathematics alone would have made Bessel famous. A system of analysis that he worked out, known as Bessel's functions, is used even now in the field of nuclear physics.

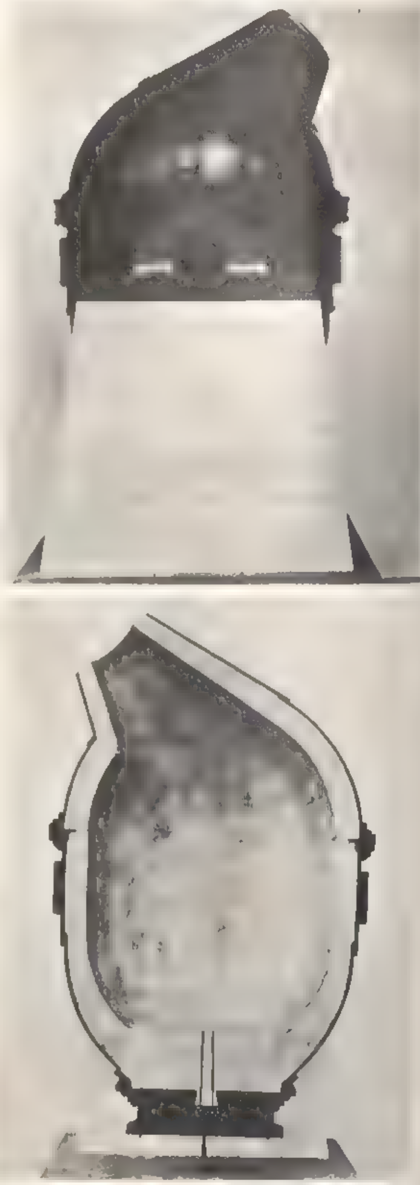
BESSEMER, SIR HENRY (1813–1898)

Seeking to build a cannon sturdy enough to fire a projectile of his invention, Henry Bessemer hit upon the first process for making inexpensive steel in large quantities. In 1856 he announced his discovery to the British Association for the Advancement of Science.

Steel was scarce compared with iron in the mid-nineteenth century, and the process for making it was long and complicated. Bessemer found that the removal of carbon, which was necessary for converting iron to steel, could be done easily by blasting compressed air through the molten pig iron.

Bessemer, the son of a typefounder, was born near Hitchin, Hertfordshire, England. He first applied his self-acquired engineering education to the development of typesetting machines. When he was seventeen years old, he opened his own small business in London. Always a versatile inventor, he devised a perforating punch to replace postage stamps; machines for working graphite for pencils; and methods of gilding and bronzing metals. Later in life, he invented a steamship stabilizer,

Sir Henry Bessemer



In 1856 Henry Bessemer announced his invention of an inexpensive process of making steel. Its essential feature was a converter in which air was blown through molten pig iron to purify it, at the same time generating enough heat to keep the metal in a hot and liquid state. The resultant mild and malleable steel was widely used in the construction of bridges, railways, and ships.

a large telescope, and a solar furnace.

At the time of the Crimean War (1854–1856), Bessemer designed a rotating artillery shell, but the cast-iron cannon of this time was too weak to fire it. Looking for a stronger material, he began to experiment with methods. The result was Bessemer steel, which made him [illegible]

Sheffield was the center of high-grade steel manufacture in England, and it followed that Bessemer should set up a factory there to produce his steel. The demand for steel was great, particularly for developing railroads. Steel rails were cheaper, longer lasting, and easier to maintain than iron rails. Its ductility, toughness, and resistance to corrosion made Bessemer steel desirable also for boilers, locomotives, bridges, high buildings, and ships. The latter use was especially [illegible]rtant in Great Britain, which then [illegible] half the marine tonnage of the [illegible]

Many honors came to Bessemer, who had [illegible]l the epoch of steel. He was made [illegible]low of the Royal Society and was [illegible]d in 1879.

BETHE, HANS ALBRECHT (1906–   )

The German physicist Hans Bethe received the 1967 Nobel Prize in physics for his theories on energy production in the stars. Among the important contributions of this pioneer in nuclear research was the first development of the theory of electron-positron pair creation, resulting in the Bethe-Heitler formula. He was also a leader in the movement among scientists to curb the use of atomic weapons.

Bethe was born in Strasbourg, Germany (later France), and attended the universities of Frankfurt and Munich. When Hitler came to power in 1933, Bethe left Germany for England, where he lectured for two years. In 1935 he joined the faculty at Cornell University at Ithaca, New York.

In 1937 Bethe began the calculations for a revolutionary theory of how the energy in stars is produced. His new theory was that hydrogen nuclei fuse with one another to form helium nuclei. The energy produced by this fusion is enormous. The process is similar to the phenomenon that produces the explosive energy in the hydrogen bomb.

In 1943 Bethe joined Enrico Fermi and J. Robert Oppenheimer to work on the development of the atomic bomb at the Scientific Laboratory at Los Alamos, New Mexico. He was made head of the theoretical physics division, a position he held until 1946. After Hiroshima, Bethe led a group of scientists in urging for international control of atomic energy

Hans Bethe

and in opposing all atomic testing and was instrumental in obtaining the limited test-ban treaty of 1963. He also aided the development of atomic power reactors, intercontinental ballistic missiles, and antimissile defense.

His many awards included the Atomic Energy Commission's Fermi Medal, Germany's Max Planck Medal, the National Academy of Sciences' Draper Medal, and the Royal Astronomical Society's Eddington Medal. In 1944 he was elected to the National Academy of Sciences.

BINET, ALFRED (1857–1911)

One of the two intelligence tests most commonly used in the United States is the Stanford-Binet scale originally devised by the French psychologist Alfred Binet. He is famous not only for his intelligence scale but also for his general research into learning problems.

Binet was born in Nice, France, and studied law and medicine in Paris. In 1892 he became assistant director of the psychological laboratory at the Sorbonne and in 1895 succeeded Henri Beaunis as director. That same year he and Beaunis founded the first French journal of psychology.

Experimentation was very important in Binet's work, but it had to be on an individual personal level—for example, using interviews or questionnaires. In his research and testing he was always mindful of the emotional factors in learning. Binet attached little or no importance to mechanical experiments in laboratories.

In the early 1900s the Paris school authorities requested that Binet develop testing procedures for slow-learning children. In 1905 Binet and Théodore Simon published an intelligence scale for children aged three to thirteen. Each child earned a mental age (MA) expressed as an average; that is, a child with an MA of nine performs as well as the average nine-year-old. The MA is meaningful only when expressed in combination with chronological age. If a child has an MA of nine at the age of six, he is bright. If, however, he has an MA of nine at the age of twelve, he is slow.

Before he died, Binet was revising his scale. After his death, revisions of his scale were carried on at Stanford University in the United States. Lewis M. Terman of the Stanford psychology department made the first revision in 1916. Terman was the man who coined the term *intelligence quotient* (IQ); to determine a child's IQ, he divided his mental age by his chronological age and then multiplied by 100 to make a manageable whole number. Binet's original scale held up well for children of average or below average intelligence, but it was not so accurate for children who were above average. Terman added items of greater difficulty to compensate for this problem.

Alfred Binet

Also, since it was difficult to measure an older person's IQ under Binet's system, Terman assigned a chronological age of fifteen to everyone over the age of sixteen. Later Terman made further revisions, and the Stanford-Binet scale became firmly established with U.S. educators and psychologists.

BJERKNES, VILHELM FRIMANN KOREN (1862–1951) **and JACOB AALL BONNEVIE** (1897–   )

One of the founders of modern weather forecasting was the Norwegian physicist and meteorologist Vilhelm Frimann Koren Bjerknes, who teamed with his son Jacob to make some exciting discoveries. The elder Bjerknes was also well known for his study of electrical resonance, which was influential in the development of radio.

Vilhelm, the son of a mathematics professor, was born in Oslo and studied at the university there. He became renowned as a teacher and taught over a period of almost forty years at the uni-

versities of Oslo; Stockholm, Sweden; and Leipzig, Germany; and at the Bergen Geophysical Institute.

Jacob, who was born in Stockholm, Sweden, received his doctorate from the University of Oslo in 1924. He studied with his father and worked with him for a number of years. In 1939 Jacob emigrated to the United States and began teaching at the University of California. He went through the naturalization process and became a U.S. citizen in 1946.

Vilhelm Bjerknes

In 1904 Vilhelm announced the details of his ambitious weather prediction system. He was already known in scientific circles for his theorems on physical hydrodynamics, which he applied to the sweeping great motions in the oceans and in the atmosphere. He and a group of his Bergen assistants, including his son, discovered the origin of cyclones.

During World War I father and son organized a network of weather stations in Norway. After studying the data from these stations, they originated the theory of polar fronts. Television viewers are generally familiar with the line drawn on the weather map to indicate a new front, which is actually the boundary of an air mass. Fronts are extremely important to modern weather prediction.

BLACKETT, PATRICK MAYNARD STUART (1897–)

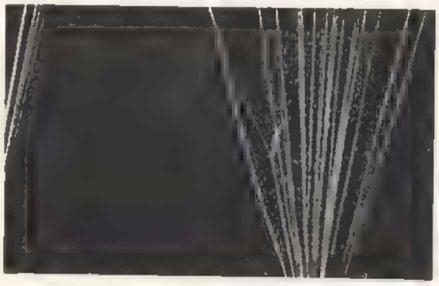
For his discoveries concerning cosmic radiation, the British physicist Patrick Maynard Stuart Blackett received the Nobel Prize in physics in 1948. He refined the basic cloud chamber devised by Charles Thomson Rees Wilson so that it could be used to study cosmic radiation.

In 1935 Blackett demonstrated the conversion of energy into matter, confirming Albert Einstein's equation $E = mc^2$. Other scientists had already demonstrated the opposite—the conversion of matter into energy—but it remained for Blackett to complete the proof.

Patrick Blackett

Blackett was born in London. In his early teens he fought in World War I. At Cambridge University he studied under the great physicist Sir Ernest Rutherford; he graduated from Cambridge in 1921.

He was engaged in research at the Cavendish Laboratory for ten years. From 1933 to 1937 he served as professor of physics at Birkbeck College, the University of London. Then he took a position as professor of physics at the University of Manchester and taught there until 1953. (During World War II he worked on the development of the atomic bomb and radar.)



A cloud chamber permits the path of a single elementary particle to be followed in detail and is useful for studying the dynamics of the collisions of single particles with atoms and electrons. Patrick Blackett's cloud chamber pictures of the bombardment of nitrogen by alpha rays, with the ejection of the proton from the nitrogen nucleus, were the first to show normally stable nuclei being attacked by high-energy particles and the resultant disintegration of the nucleus.

In 1953 he was appointed professor and head of the physics department of the Imperial College of Science and Technology, the University of London. In 1965 he was named professor emeritus and senior research fellow of the college.

The Royal Society of London elected Blackett a fellow in 1933. He served as president of the society in 1967.

BLOCH, FELIX (1905–)

The 1952 Nobel Prize in physics was awarded to the Swiss-American nuclear physicist Felix Bloch for developing a new method for measuring the magnetic properties of atomic nuclei in solids. The method became important for research in physics and chemistry. Bloch shared the Nobel Prize with E. M. Purcell of Harvard University, who discovered the same phenomenon at about the same time. (*See* Edward Mills Purcell.)

Felix Bloch

Bloch entered the Swiss Federal Institute of Technology in Zürich, his native city, with the intention of becoming an engineer; but after a year he turned to physics. He won his doctorate at the University of Leipzig, Germany, in 1928 with a thesis on metallic conduction. Working with leading theoretical physicists at institutions in the Netherlands, Denmark, and Italy, Bloch became known for his work in solid-state, magnetism, and the stopping of charged particles in matter.

He joined the staff of Stanford University in Palo Alto, California, in 1934, eventually becoming a professor of physics. In 1939 Bloch produced the first accurate measurement of the magnetic properties of the neutron.

During World War II he worked on atomic energy for the Manhattan District and on radar countermeasures. After returning to Stanford in 1945, he concentrated on the study of the magnetic fields of atomic nuclei. Others had investigated the magnetic fields of atomic nuclei by working with beams of gaseous atoms or molecules. Bloch devised a method of determination for liquids or solids. His method involves detecting radio waves from nuclei subjected to magnetic and electromagnetic fields.

In 1954 and 1955 he served as the first director general of the European

Laboratory for Nuclear Research in Geneva, Switzerland. His later researches after returning to Stanford extended nuclear [illegible]duction to studies of nuclear and mole[illegible]ar structure.

Blo[illegible] became an American citizen in 1939[illegible]e was elected to the National Aca[illegible] of Sciences in 1948. He becam[illegible] fellow of the American Physics Soci[illegible] and served as its president in 196[illegible]

BLO[illegible] KONRAD EMIL (1912–)

D[illegible]eries by Konrad Emil Bloch, Ger[illegible] American biochemist, concerning [illegible] character of cholesterol were rew[illegible] with the 1964 Nobel Prize in p[illegible]ology or medicine. Bloch's cowin[illegible] was Feodor Lynen of Germany. (*See* [illegible]dor Lynen.)

Konrad Bloch

Bl[illegible] his colleagues showed that acet[illegible] furnishes building blocks for chol[illegible] in animal tissue. The biosynth[illegible] of cholesterol—a solid alcohol found [illegible] animal cells—has thirty-six steps, [illegible]th the hydrocarbon squalene as a key intermediate. Discovery of this pathway had important applications in medicine, physiology, and chemistry.

Bloch was born in Neisse, Germany. In 1934 he received his bachelor's degree in chemical engineering from the Technische Hochschule in Munich. After a short stay at a Swiss research institute, Bloch emigrated to the United States in 1936. He entered Columbia University as a graduate student, earned his doctorate in 1938, and began research in the isotopic analysis of cell metabolism as an associate of Rudolf Schoenheimer, who "tagged" molecules for studying metabolic processes in the living cell. In 1946 he became a member of the biochemistry department of the University of Chicago and remained there until 1954, when he was appointed professor of biochemistry at Harvard University.

Bloch became a U.S. citizen in 1944. He was elected to the National Academy of Sciences in 1956.

BOHR, NIELS HENRIK DAVID (1885–1962)

One of the most influential scientists of the twentieth century, Niels Henrik David Bohr developed the first consistent explanation of atomic structure. The Danish physicist proposed his theory in 1913, when he was only twenty-eight years old. He was awarded the 1922 Nobel Prize in physics for his achievements in the study of the structure and radiations of atoms.

Bohr's work was essential to the understanding of nuclear fission, and he labored zealously on behalf of peaceful uses of atomic energy. He received the first Atoms for Peace Award in 1957.

Bohr was born in Copenhagen, Denmark, and studied physics at the University of Copenhagen, where his father was a professor of physiology. At the age of twenty-two, Bohr won a gold medal of the Danish Academy of Sciences and Letters for his investigation of the surface tension of water. After receiving his doctorate in 1911, he went to England for further study. There he worked briefly at Cambridge University and then went to the University of Manchester to work with Ernest Rutherford, who had recently discovered the atomic nucleus. Bohr taught theoretical physics at Manchester from 1914 to 1916 and at Copenhagen thereafter. In 1920 he became director of the new Institute of Theoretical Physics created for him within the university. He held that position until his death, when his son Aage Niels Bohr succeeded him. Scientists from all parts of the world went to Denmark to confer and study with Bohr.

In 1939 Niels Bohr (right) and Enrico Fermi, innovators of the age of nuclear physics, attended a conference at Princeton University to discuss the possibility of obtaining a new, highly concentrated source of energy through the fission of uranium atoms.

Shortly after German scientists split the uranium atom in 1938, Bohr learned of the event and its significance as he was preparing to visit the United States. The discovery of fission provided a new possibility of sustained fire—a chain reaction. Arriving in the United States in January 1939, Bohr discussed the discovery with Albert Einstein, Enrico Fermi, and other scientists. Bohr worked during the winter of 1939-1940 at Princeton University. With J. A. Wheeler, he theorized that the fission observed with uranium comes from ^{235}U. This prediction was confirmed.

When Nazi Germany occupied Denmark in 1940, Bohr took an active part in the resistance movement. Under threat of arrest in 1943, he escaped to Sweden with his family in a crowded fishing boat. From Sweden he was flown to England in an unarmed military plane. Eventually he went to the United States as a consultant to scientists who were developing nuclear weapons. Although he took part in the atomic bomb project at Los Alamos, New Mexico, he voiced his concern about such a potential for disaster.

After the war, Bohr returned to Copenhagen. Convinced that the free exchange of people and ideas among countries is necessary for keeping peace, he addressed an open letter to the United Nations in 1950 advocating an "open world." He promoted the 1955 Geneva Summit Conference on Atoms for Peace. He was instrumental in founding the European Center for Nuclear Research at Geneva and the joint Nordic Institute for Theoretical Atomic Physics in Copenhagen. When the Danish Atomic Energy Commission was founded, Bohr became its chairman. He was president of the Royal Danish Academy of Sciences from 1939 until his death.

BOOLE, GEORGE (1815–1864)

The works of the English mathematician and logician George Boole, neglected for almost sxity years after their publication, were discovered and evaluated according to their true importance by two later mathematicians, Alfred North Whitehead and Bertrand Russell. Boole's work was not readily comprehensible. It was, in fact, ahead of its time; one of its applications, for exam-

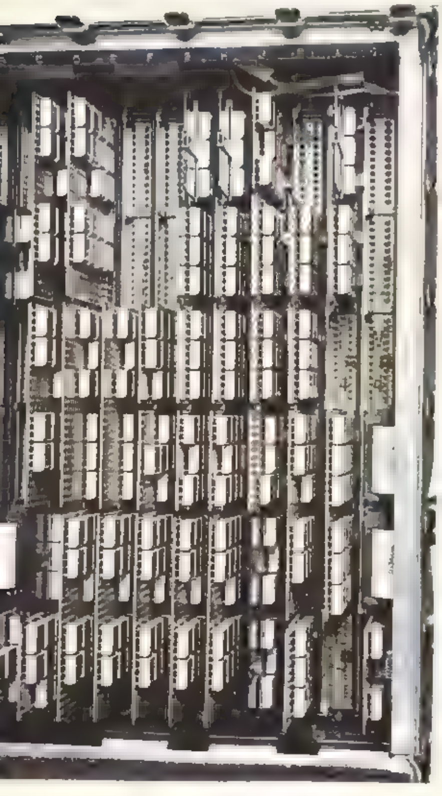
ple, lies in the construction of large automatic electronic computers. His works must unquestionably be considered fundamental to modern mathematics.

When, as a result of having delivered a lecture in spite of bad weather, George Boole contracted the pneumonia that was to carry him to his grave before he was fifty, he insisted on summoning a doctor who had been dismissed by the hospital for breaking certain regulations. Such a proof of trust, Boole said, ought to give encouragement and solace to a man in trouble.

Boole was tormented by one great anxiety: the thought that, after his death, his children might be brought up by people who were considered religious in the ordinary sense of the word. This shows that Boole's ideas on politics, religion, and morality were decidedly anticonformist, a rather unusual thing for an Englishman of the nineteenth century. Yet there had been a time when he had thought of entering the church, but he subsequently changed his mind—fortunately for the church, which would have had a clergyman without a vocation, and for mathematics, which gained an innovator to whom it owes a number of fundamental discoveries. Boole's idea of taking orders sprang from a desire to improve his social position; he was not a social climber but simply aspired to some form of liberal profession, from which he was debarred by the fact that he was the son of a modest shopkeeper. Small trade was then a much-despised occupation, and those engaged in it inevitably belonged to an inferior class, whose children could go only to second-rate schools and had little possibility of advancement on the basis simply of their energies and abilities. These were the conditions of life during the Industrial Revolution, and Boole had to struggle hard and long to escape a destiny that seemed preordained and inevitable.

George Boole

George Boole's long-neglected algebra, which was developed to solve problems of pure logic, now has many important applications, ranging from an understanding of documents and statutes to the making of electronic computers.



Boole's determination to improve his lot was already apparent when he was a pupil in the National School in Lincolnshire, where he was born. The school's curriculum did not include Latin or Greek, a knowledge of which was considered absolutely necessary for anybody wishing to make his way in the field of culture or in the society of the time.

Convinced of the need for a classical culture that his school could not offer him, Boole decided to study on his own. He learned the first rudiments of Latin from a friend of his father who had a book shop. After only a few lessons he had to continue alone. Yet by the time he was twelve, he had managed to learn enough Latin to produce a verse translation of an ode by Horace. His father, full of understandable pride, had this translation published in a Lincoln newspaper. The result, however, was hardly gratifying. It was thought that the translation could not have been the work of such a young boy; yet at the same time a number of mistakes were pointed out that indicated his inadequate knowledge. All this did not prevent Boole from studying Greek as well; moreover, his father, who had some knowledge of mathematics, encouraged him to work at this subject, too. Boole began to do so with passionate interest but in no way neglected his classical studies, which seemed to him to be filled with much more promise.

At an early age Boole had to begin maintaining his family, since his parents were by then old and poor. After leaving the National School, he therefore followed a commercial course that allowed him to take a teaching post in a school in Doncaster and then in one in Waddington. He was only sixteen, barely older than his pupils, and during this time he spent his nights pondering his problems. It was not easy to reconcile his aspirations for a better life with the material cares of having to provide for his family. It was in these circumstances that Boole thought, as a last resort, of entering the church. For four years he studied privately, working during the day and depriving himself of sleep at night. Although he subsequently gave up the idea of taking orders, these years of study enabled him to learn Italian, German, and French.

When he was twenty, Boole decided to open a private school in Lincoln; and, since mathematics had to be taught, he resumed his mathematical studies and subsequently began publishing his findings. His *Researches in the Theory of Analytical Transformations* was a collection of all his works that had been published between 1839 and [illegible] in the *Cambridge Mathematical Journal*. In the same year he published a paper entitled *Mathematical Analysis of Logic* which laid the foundations of the modern study of symbolic logic. He took the subject up again and expanded it as *An Investigation of the Laws of Thought*, a book that took him six years to write.

The point of departure of these studies was perhaps the algebra work on invariants with which he had started his career as a mathematician. Boole's theoretical work led to the possibility of using algebraic methods for purely logical questions. Since nobody needed his theories to construct or to understand practical things, his works fell into temporary oblivion.

In 1849 he was appointed professor of mathematics at Queen's College, Cork, Ireland, where he met his future wife, Maria Everest, the niece of a professor of Greek, who, after her husband's death, decided to carry on his work in the educational field by applying some of his ideas to the development of a more rational form of children's education.

His improved social and financial position did not distract Boole from his studies and his teaching, which he considered a mission. In 1859 and 1860 he published two other works, one on differential equations and one on the calculations of finite differences, a subject that had fascinated him since the time of his earliest studies.

BORDET, JULES (1870–1961)

Jules Bordet, Belgian physician and bacteriologist, was rewarded with the 1919 Nobel Prize in physiology or medicine for important discoveries in immunology. His controls and techniques contributed fundamentally to the founding of that science.

Jules Bordet

One of Bordet's early discoveries and perhaps his best known is that two substances are required in blood serum in order to destroy a disease germ in the host organism. One is an antibody (a substance that counteracts bacterial infection) and the other is a component now known as *complement*. If a disease germ enters the bloodstream of a person who has acquired antibodies as a result of immunization or previous exposure to the disease, complement either is absent or it is present in amounts below normal. Bordet showed that when an antibody reacts with an antigen (a substance injected into animal tissue to stimulate production of antibodies), complement is used up. This process known as *complement fixation* became the basis for identifying many disease organisms, including typhoid fever, tuberculosis, and syphilis.

Bordet, the son of a schoolmaster, was born in Soignies, Belgium, and was educated at the University of Brussels. He earned his medical degree in 1892 and worked for several years at the Pasteur Institute in Paris, France. In 1901 he returned to Brussels to found and direct a Pasteur Institute for the province of Brabant. Soon he was appointed professor of bacteriology at the University of Brussels.

In 1906 Bordet was instrumental in isolating the whooping cough bacillus, later known as *Bordetella pertussis*. He was also responsible for developing a method of immunizing against it.

BORN, MAX (1882–   )

The German theoretical physicist Max Born won the 1954 Nobel Prize in physics for his role in the development of quantum mechanics. He shared the prize with another German physicist, Walther Bothe. Born also did important work on the space-lattice theory of crystals and on atomic structure. (*See* Walther Wilhelm Georg Franz Bothe.)

He was born at Breslau and educated at the universities of Breslau, Heidelberg, Zürich, and Göttingen. He received his doctorate from the University of Göttingen in 1907. In 1921 he became professor of theoretical physics at Göttingen. Born left Germany in 1933, after Hitler came to power. He went to Great Britain and taught at Cambridge, becoming a British citizen in 1939. In 1936 he was appointed to the Tait Chair of Natural Philosophy at the University of Edinburgh, a post he held until his retirement in 1953.

One of Born's most significant contributions was his work in developing a mathematical basis of quantum mechanics. He formed his mathematical interpretation of the behavior of electrons by conducting studies of electron waves. Born tested the quantum theory of the atom propounded by Niels Bohr. This early quantum theory regarded electrons as particles. By performing statistical studies on wave functions, Born developed a mathematical interpretation that more accurately described the behavior of electrons.

Max Born

Born was strongly opposed to the military uses of modern scientific knowledge. He wrote many articles and books on this subject, stressing the responsibility of scientists. In 1955 he was made a foreign associate of the U.S. National Academy of Sciences.

BOSCH, KARL (1874–1940)

The most significant achievement of Karl Bosch was his development of an industrial operation for the commercial production of ammonia based on the Haber process. The commercial method is often referred to as the Haber-Bosch process. For his discovery and development of chemical high-pressure methods involving the production of ammonia, the German industrial chemist shared the 1931 Nobel Prize in chemistry with Friedrich Bergius. (*See* Friedrich Bergius.)

Bosch was born at Cologne, Germany, and educated at the University of Leipzig. He studied there with Johannes Wislicenus and received his doctorate in 1898 for research in organic chemistry. Bosch was also trained as an engineer and acquired some practical workshop experience.

His schooling completed, Bosch went to work for the Badische-Anilin-und Sodafabrik, which later became the I.G. Farben-Industrie; in 1925 Bosch became the president. It was at this company, in 1909, that he undertook the task of developing an industrial operation based on the Haber process. Fritz Haber had earlier succeeded in synthesizing ammonia directly from hydrogen and nitrogen. (*See* Fritz Haber.)

The development of the Haber-Bosch process involved more than 20,000 experiments. In solving one of the basic problems of adapting the Haber process for commercial use, Bosch substituted Haber's carbon-steel container with one of alloy steel to hold the reacting gases. The Haber-Bosch process became important in the manufacture of explosives and fertilizer.

Another of Bosch's experiments in high-pressure chemical engineering was his attempt to obtain urea from ammonium carbamate. He developed the methanol synthesis used in making formaldehyde. He also devoted time to the problem of hydrogenation and was involved in the production of synthetic rubber. His process for the commercial production of hydrogen consisted of passing a mixture of steam and water gas over a suitable catalyst at high temperature.

In 1935 he succeeded Max Planck as the head of the Kaiser Wilhelm Society, which was later renamed the Max Planck Society. Bosch remained in Germany after Hitler came to power, but he never accepted Nazi principles. He died at Heidelberg well before the end of World War II.

BOTHE, WALTHER WILHELM GEORG FRANZ (1891–1957)

The German physicist Walther Bothe is credited with having introduced the coincidence method into modern physics.

For the coincidence method and for the discoveries resulting from this method, Bothe shared the 1954 Nobel Prize in physics with Max Born. The coincidence method is a way of measuring short intervals of time—a billionth of a second or less. Bothe's coincidence method, applied to counting techniques, proved valuable in research involving cosmic radiation and nuclear reactions and in studying the Compton effect. (*See* Max Born.)

Bothe was born at Oranienburg, Germany. He attended the University of Berlin and studied with Max Planck, receiving his doctorate in 1914. During World War I he served with the military and was held in Russia as a prisoner of war from 1915 to 1920. After his release he returned to Germany and taught physics at the University of Berlin and worked at the radioactivity laboratory of the Physikalish-Technische Reichanstalt.

Bothe worked on many of his experiments with Hans Geiger, the inventor of the Geiger counter. Bothe's early research was on the scattering of alpha and beta rays and on the ejection of electrons by x-rays. In connection with his x-ray research, Bothe first employed a modified Geiger counter in 1924 for use in a coincidence experiment.

In 1929 Bothe devised his coincidence method for studying cosmic rays. This method employed two Geiger counters, one placed above the other. An event of coincidence would be recorded when both Geiger counters registered almost simultaneously. This occurred only when a cosmic-ray particle descended vertically through both Geiger counters.

In 1930 Bothe found unusual radiation being emitted from beryllium that had been bombarded by alpha particles. This strange effect was later identified by Sir James Chadwick as the neutron. Another of Bothe's accomplishments was his part in the construction of Germany's first cyclotron, which was completed in 1944.

Bothe became professor of physics and director of the Institute of Physics at the University of Giessen in 1930. Two years later he moved on to the University of Heidelberg. In 1934 he became director of the Institute of Physics at the Max Planck Institute for Medical Research. After 1946 he also held the chair of physics at the University of Heidelberg.

"BOURBAKI, NICOLAS"

The name "Nicolas Bourbaki" does not belong to any one individual but is the pseudonym of a group of mathematicians, most of whom are French. These mathematicians began in the later 1930s to write a definitive survey of all mathematics, *Elements of Mathematics*, under the name "Nicolas Bourbaki." This is an ongoing work, consisting by the late 1960s of more than thirty volumes.

The members of the group change from year to year and keep their identity a secret. It is believed, however, that the original group included the prominent mathematicians H. Cartan, C. Chevalley, J. Dieudonné, and A. Weil. There is a fairly constant turnover within the group, older members dropping out and younger members joining, with the result that the group has retained a youthful spirit. At any given time there are between ten and twenty mathematicians in the group. At times the group has included some American mathematicians. The members have tried to convince the public that there is such a person as Nicolas Bourbaki, and Bourbaki went so far as to apply for membership in the American Mathematical Society. The application was turned down on the ground that Bourbaki was not an individual.

It is not known for certain how the group happened to choose their pseudonym. There is speculation that the last name was taken from General Charles Denis Sauter Bourbaki; a statue of him is situated at Nancy, France, where some members of the group are known to have taught. As for the first name, it is possible that this represents St. Nicholas bringing gifts to the world of mathematics.

The most distinctive features of Bourbaki's approach to mathematics is the strict adherence to axiomatic methods, the use of unconventional terminology (which has become widely accepted in the mathematical world), and the insistence that each part of mathematics be made as general as possible in order to broaden its range of applicability. Bourbaki divides mathematics into parts depending upon their structure. In the Bourbaki arrangement, mathematics begins with set theory and then proceeds through algebra, general topology, functions of a real variable, topological vector spaces, the general theory of integration, and on to other parts of mathematics.

Inspiration for the introduction of the new mathematics into school curricula has been attributed to Bourbaki, but this was apparently not Bourbaki's intent. The Bourbaki approach was not meant to be used in the teaching of mathematics—not even at the college level. It was intended for the use of trained mathematicians so that they might increase their understanding of the subject.

BOVET, DANIEL (1907–   )

A pioneer in the development of antihistamines and muscle relaxants Daniel Bovet won the 1957 Nobel Prize in physiology or medicine. Discoveries made by the naturalized Italian pharmacologist led to major advances in the practice of medicine.

Bovet was born in Neuchâtel, Switzerland, of French parents. He received his doctor's degree in zoology and comparative anatomy in 1929 from the University of Geneva. In 1932 he began to do research at the Pasteur Institute in Paris, France, where he became head of the laboratory for therapeutic chemistry in 1937. By that time, Bovet had synthesized a series of antihistamines. Histamine, which is present in all body tissues, is believed to be the causative agent in producing allergic symptoms; and antihistamines relieve the discomforts associated with many allergies.

Curare, an alkaloid found in the root of several South American shrubs, is notorious as the poison used by some South American Indians to poison the tips of their arrows. The poison kills by relaxing the victim's muscles to the state of paralysis (it does not work on the central nervous system). Bovet realized that with modification and careful dosage such a muscle relaxant would be advantageous when used along with an anesthetic in surgery. During the late 1940s he synthesized several compounds similar to curare that affected anesthetic practice.

Early in his career Bovet furthered the study of sulfa drugs with his discovery that sulfanilamide is the active bactericide responsible for the power of the compound prontosil to kill streptococci in the body. Bovet also did some research

Daniel Bovet

on tranquilizers and on oxytocin, a post-pituitary hormone that stimulates uterine contraction in childbirth.

In 1947 Bovet became head of the laboratory of therapeutic chemistry at the Istituto Superiore di Sanità in Rome, Italy. Later he was appointed professor of pharmacology at the University of Sass[illegible]

Bovet published widely on biology, general pharmacology, chemotherapy, pharmacology of the sympathetic nervous system, therapy of allergic conditions, antihistamine syntheses, and curare.

Bovet received, in 1946, the title of Knight of the Legion of Honor of France and, in [illegible] that of Grand Officer of the Order of Merit of the Italian Republic. He was also honored with degrees from many European universities.

BOWEN, NORMAN LEVI (1887–1956)

One of the major researchers in, and leaders of the magmatist school of geology was the pioneering American geologist Norman Levi Bowen. He conducted important studies of phase equilibriums among silicate systems. His findings, particularly regarding the reaction principle, are considered to be among the most important contributions to petrology made in the twentieth century.

Bowen conducted his phase-equilibrium studies under laboratory conditions. Many of his fellow geologists were skeptical of laboratory experiments, arguing that equilibrium rarely occurs in nature. The emphasis at that time was on fieldwork. Bowen, nevertheless, believed that if the physical chemistry of geologic processes was studied under equilibrium conditions, the researcher could evaluate the factors contributing to the failure to attain equilibrium in nature. He regarded the laboratory studies as a way of providing a chemical basis for geological hypotheses.

He brought together the results of his work on phase equilibriums in silicates in his book *The Evolution of the Igneous Rocks* (1928). Through the years the findings of his research gave new insight into such geological puzzles as the origin of dolomite, the metamorphosis of impure carbonate rocks, and the role of the residual systems in petrogenesis.

Bowen, the son of British immigrants, was born at Kingston, Ontario, Canada. He studied chemistry and mineralogy at Queen's University in Kingston, earning his master's in 1907. In 1909 he was also awarded a bachelor's from the university's School of Mines. He received his doctorate from the Massachusetts Institute of Technology in 1912. From 1907 to 1910 he spent his summers doing fieldwork for the Ontario Bureau of Mines and for the Geological Survey of Canada.

Norman Bowen

In 1912 Bowen became an assistant petrologist at the Carnegie Institution of Washington, D.C. He left the institution to become a professor of geology at Queen's University in 1919 but returned a year later. From 1937 to 1947 he held the chair of petrology at the University of Chicago. In 1947 he again returned to the Carnegie Institution as a petrologist and remained there until his retirement in 1952.

Bowen received many awards for his work, among which were the Roebling Medal of the Mineralogical Society of America and the Penrose Medal of the Geological Society of America. He was elected president of the former in 1937 and of the latter in 1946. He became a member of the National Academy of Sciences in 1935 and a foreign member of the Royal Society of London in 1949.

BOYLE, ROBERT (1627–1691)

Though a chemist, physicist, theologian, linguist, student of medical sciences, and man of the world, Robert Boyle is known chiefly for the law on the compressibility of gases that bears his name. He, in fact, owes his fame to his studies on air and to his discovery of new experimental methods for collecting gases.

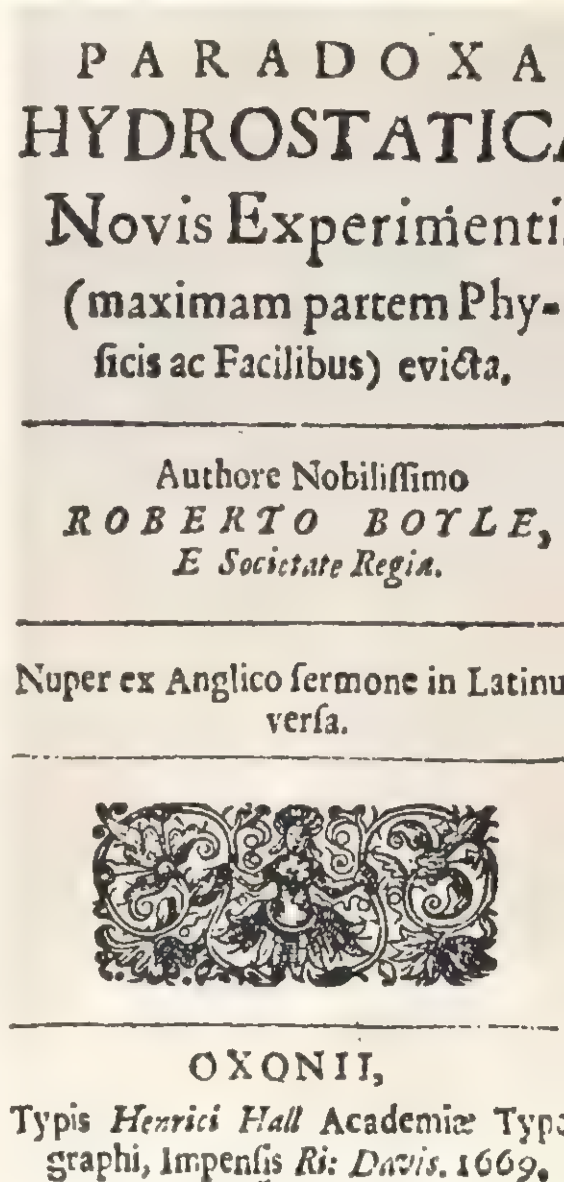
His research, which deals principally with the properties of gases, is directly derived from that of Galileo and his followers, particularly Evangelista Torricelli, but then proceeds in a completely autonomous and independent way.

Robert was the fourteenth child, and the seventh son, of Richard Boyle, the earl of Cork. His mother died when he was only three; and he was brought up by tutors, as befitted a boy of his station. He gave early proof of a prodigious memory and at the age of eight was sent to Eton.

The deep religious feeling that is apparent in his first writings, together with frequent memories of his lost mother, date from his childhood years, which

were spent rather dismally in the great castle of Lismore. Boyle was fortunate enough to escape the conventional Aristotelian teaching that still prevailed in the great universities of the time. He spent three years (1635–1638) at Eton and then lived for a short time at Stalbridge in Dorset, in a mansion that belonged to his family. In 1639 he was sent on an educational tour of the Continent with a Swiss tutor, who wisely confined himself to teaching him the first rudi-

Robert Boyle's *New Experiments*, expounding his theories on the chemistry of gases, was published originally in English in 1660 but also appeared in a Latin translation in 1669.



PARADOXA
HYDROSTATIC[A]
Novis Experimenti[s]
(maximam partem Phy-
ficis ac Facilibus) evicta,

Authore Nobiliffimo
ROBERTO BOYLE,
E Societate Regia.

Nuper ex Anglico fermone in Latinu[m]
verfa.

OXONII,
Typis *Henrici Hall* Academiæ Typ[o]graphi, Impenfis *Ri: Davis*. 1669.

ments of classical culture. Otherwise, the tutor left him free to study the subjects that interested him most, such as languages and, above all, mathematics and physics. He was twelve when he set out on this journey, which should have lasted a year but in fact continued for almost five years because of the civil wars that were raging in England and Ireland at that time. After a long stay in Geneva, Switzerland, he went to Italy, where he spent the winter of 1641, pondering what he himself defined as "the new paradoxes of the great searcher Galileo." These undoubtedly had a strong influence on his atomistic notions, causing him to abandon the Aristotelian vision once and for all.

When he returned to England, he learned that his father had died penniless in London the year before, while the city was in the throes of the civil war between Royalists and Parliamentarians. Lost as he was in the confusion caused by these events, the boy was saved by his sister Catherine, who had become Viscountess Ranelagh. She looked after him like a mother, offered him a home, and wisely advised him against joining the Royalist army, which was subsequently defeated.

At the beginning of 1645, Robert took up residence in the family mansion in Dorset, where he stayed for seven years, devoting himself to theology and chemistry and interrupting his studies only for expeditions, usually to the Continent, to search for new instruments for his experiments. These years of almost total isolation, while enabling him to read, reflect, and correspond with famous scholars, accentuated certain negative traits in his character—particularly a tendency to hypochondria, which, however, fortunately passed with the years.

The doctor who looked after his health, which was never strong, declared that Boyle was afflicted by three infirmities: an excess of reading, a fear of illness, and a mania for acting as his own doctor. Medicine was indeed one of Boyle's interests, and in 1655 he was awarded an honorary degree in medicine. He would prepare strange potions for himself and for his friends and is said to have even performed anatomical dissections, though others affirm that these would have been too much in conflict with his sensitive nature.

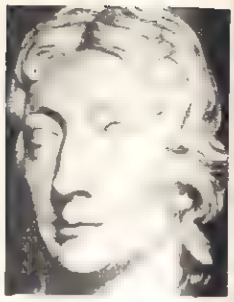
Certainly Boyle's emotional temperament made him subject to moral scruples. This is shown by the doubts that tormented him during a stay on his Irish estates (1652–1653). He began to wonder whether it was right to enrich oneself by the poor workers' incessant toil. Finally, he decided to use most of his income to improve their lot, and he kept this philanthropic attitude throughout his life.

In the meantime his name and his interests were becoming known in the circles of the young thinkers who, rebelling against the old Aristotelian methods, were promoting a new natural philosophy based on the experimental science favored by Galileo, René Descartes, and Sir Francis Bacon. For this purpose they had founded the Invisible College and were in the habit of meeting at Gresham College, London, and later at Oxford. In 1653 they invited Boyle to join them and urged him to settle in the university town, which he did the following year. Boyle immediately found himself among friends who became his efficient collaborators. Boyle, in fact, needed assistants because he had a highly individual method of working at several experiments and treatises simultaneously. Despite his dialectical skill as a philosopher and theologian, Boyle avoided all universal systems in the scientific field and preferred to base his studies on experimental evidence. He had realized that chemistry, with its experiments, could be of use to natural philosophy, which, in its turn, supplied chemistry with a theoretical foundation.

Thus, he attacked the alchemists (*New Experiments* and *Philosophical Essays*), though many of his experiments were aimed at obtaining the transmutation of metals into gold, and he also attacked the Aristotelian notions of matter and motion with his corpuscular theory (*Sceptical Chymist*).

He retained the idea, derived from classical antiquity, of universal, impenetrable matter, from which all bodies originate as a result of "accidents." This universal matter has three fundamental properties—size, shape, and movement—and is composed of innumerable "corpuscles" of different types and sizes. These can unite in indivisible groups, each of which is a chemical substance or an element.

In 1660 Boyle published *New Experiments*, in which he expounded his ideas on the chemistry of gases. Air, he affirmed, has a perceptible weight and therefore exerts pressure; it is not homogeneous and contains a small part of the "vital quintessence" that is essential for life. The work gained many supporters and naturally also attracted the attacks of the Aristotelians and Cartesians. The curious



Robert Boyle

fact is that, in the second edition of his work, merely as a reply to the objections of a Dutch physicist, Boyle added an appendix containing the famous law on gases, according to which the volume varies inversely to the pressure. The strange ideas on the atomistic notion of matter that Boyle defends in his works can in no way detract from the credit that he justly deserves for the discovery of the law of gases.

He made this discovery after successfully perfecting Otto von Guericke's vacuum pump, with Robert Hooke's assistance. His pump, which dated from 1659, was called the machina Boyleana or the pneumatical engine. From that period, so far removed from modern technology, the obtaining of a vacuum for the study of the laws of gases has always been a necessity. Boyle's law, however, was formulated with the aid of the closed air manometer that he had constructed himself. He had poured some mercury into a U-shaped tube that was sealed at one end and had noted that the volume occupied by the compressed air at the closed end of the tube decreased as the difference in the level of the mercury in the two branches of the tube increased. These were rough experiments, but they already served to give an idea and to confirm that the volume of a gas is inversely proportional to its pressure.

Boyle's interest in pneumatics did not stop at the law of compressibility and the measuring of the weight of air. He also studied the propagation of sound in ordinary air and in the rarefied air that he could now obtain thanks to his pump. Then he conducted experiments on the effect of pressure on combustions and tackled the problem of the measurement of the specific weights of many substances. He studied respiration, crystals, and electrical phenomena. In the course of his experiments, he discovered new compounds, and he was the first to identify phosphorated hydrogen.

Boyle produced at least forty-five treatises. He did not exert himself unduly writing them but dictated them to his assistants. Meanwhile, in 1660, the ex-

members of the Invisible College, which had been disbanded, and other Royalists had founded the Royal Society, which was to have a long and productive life.

Although he had always refused a title (and even church appointments), he was always treated as a member of the nobility; and because of his fame, he was responsible for receiving the Royal Society's distinguished guests.

In order to be closer to the Royal Society, he left Oxford in 1668 and moved to his [illegible] house in London, where he lived [illegible] his death, a week after hers. Cath[illegible] proximity and affection did much [illegible]gate his introverted, highly suspicious and irascible nature, which had been further exacerbated by the many [illegible]ts, imaginary and otherwise, that af[illegible] him.

BRADLEY, JAMES (1693–1762)

The observations of James Bradley, an English astronomer, are considered by many to mark the beginning of modern physical astronomy. One of his greatest accomplishments was the discovery of the aberration of light.

Bradley's main interest was in measuring the parallax of stars in order to lend support to Copernicus' theory that the Earth revolves about the sun. The early observations of Bradley did show some displacement of the stars during a yearlong period but the observed motion was not that expected of a parallactic displacement. Reportedly he discovered the answer while taking a boat ride on the Thames River. He noticed that when the boat turned the wind vane changed direction. This discovery has also been likened to the angle at which an umbrella is held during a rainfall: straight up and down if the rain is falling vertically and if the person holding the umbrella is standing still. If the person begins walking, he must angle the umbrella in the direction of his movement to get protection from the rain. Similarly, to observe light "falling," a telescope placed on the Earth, which is in motion, must be slightly angled.

James Bradley

The amount of the angling is known as the amount of the aberration of light. If the Earth were not in motion, there would be no aberration of light. Since there is aberration of light, Bradley's discovery provided the first concrete evidence in support of Copernicus' belief about the movement of the Earth. Bradley reported his discovery to the Royal Society in 1729.

During the period of these observations, Bradley also noticed that there were small periodic shifts, or nutations, in the Earth's axis. This he attributed to directional changes in the gravitational attraction of the moon. He tested this observation during an entire revolution of the moon's nodes—18.6 years—before announcing this discovery in 1748.

In 1733 Bradley measured the diameter of the planet Jupiter. Later he made up a star map and, using his knowledge about the aberration of light and about nutations, corrected many of the small errors of his predecessors.

Bradley was born at Sherborne, Gloucestershire. His interest in astronomy was stimulated by an uncle who was an astronomer. Bradley was educated at Balliol College, Oxford. Because of his brilliance as a mathematician, he became friends with Edmund Halley and Isaac Newton. In 1718 he was elected to the Royal Society.

Bradley became a vicar in the Anglican church in 1719 but left in 1721 to accept a position as professor of astronomy at Oxford. In 1742 he became the third astronomer royal, succeeding Halley. He retired because of poor health in 1761 and died the following year at Chalford, Gloucestershire.

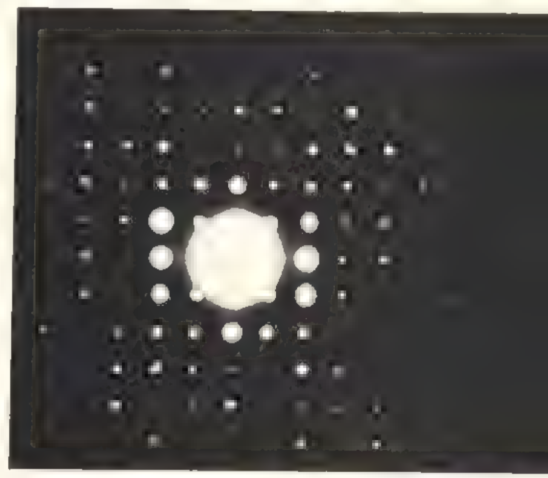
BRAGG, SIR WILLIAM HENRY (1862–1942) **and SIR WILLIAM LAWRENCE** (1890–)

The father-and-son team of Sir William Henry and Sir William Lawrence Bragg worked together on the study of crystals by using x-ray diffraction. Their method of analysis, using the x-ray spectrometer, made it possible to determine the structure of many different kinds of crystals and also aided in developing an understanding of the arrangement of atoms in matter. For their research in this area, these British physicists were awarded the 1915 Nobel Prize in physics. They were the only father-and-son team ever to have been jointly awarded the Nobel Prize.

The elder Bragg was born at Wigton, Cumberland, England. He studied at King William's College on the Isle of Man and at Cambridge. In 1886 he became a professor of mathematics and

Sir William Henry Bragg

X-ray diffraction enabled the Braggs to determine the structure of crystals and to obtain an understanding of the arrangement of atoms in matter. In a glass or crystal of sodium chloride the atoms are arranged in a regular way and in regular positions, fixed and constant, and x-rays striking or passing through at the right angle of incidence are diffracted and vary or deviate from their initial path.



physics at Adelaide University in Australia. While at Adelaide he made important discoveries about the ranges of alpha particles and carried on research involving the properties of x-rays.

In 1909 he returned to England and was appointed Cavendish Professor at the University of Leeds. In 1915 he became a professor of physics at University College, London. During World War I he worked on the development of hydrophones for submarines, and during World War II he served as chairman of Great Britain's Scientific Food Committee.

He received many honors in his lifetime, including the Rumford Medal of the Royal Society and sixteen honorary doctorates. In 1920 he was knighted, and in 1935 he became the president of the Royal Society, to which he had been elected in 1907.

The younger Bragg, William Lawrence, was born at Adelaide, Australia, while his father was teaching at the uni-

versity there. He was educated at Adelaide University and at Trinity College, Cambridge. While a student at the latter school, he began working with his father on the diffraction of x-rays. Together with his father, he wrote *X-rays and Crystal Structure* (1915).

When he was only twenty-five years old, he was awarded the Nobel Prize. In 1919 he became Langworthy Professor of Physics at the Victoria University of Manchester and in 1938 Cavendish Professor of Experimental Physics at Cambridge. Meanwhile, from 1937 to 1938, he was director of the National Physics Laboratory. He was elected to the Royal Society in 1921, was knighted in 1941, and became director of the Royal Institution in 1954.

BRAHE, TYCHO (1546–1601)

The last and one of the greatest astronomers to live and work before the advent of the telescope was the Danish astronomer Tycho Brahe. He discovered the "new star" in Cassiopeia (sometimes called Tycho's Star), corrected almost every existing astronomical measurement, and established the world's first real astronomical observatory.

Tycho was born at Knudstrup, Denmark, now a part of Sweden. He was educated at universities in Copenhagen, Denmark, and in Germany, at Leipzig, Rostock, and Augsberg. At first he studied law and philosophy, intending to make his career in politics; but after observing the solar eclipse of 1560, he changed his mind and began studying astronomy and mathematics.

For the most part Tycho had been raised by a wealthy, childless uncle. His uncle wanted him to become a lawyer and so assigned him a tutor who was to prevent Tycho from studying any subjects not connected with law. The tutor was extremely zealous in giving him lessons and exercises, but Tycho's fascination with astronomy was by then so strong that the tutor's zeal was unavailing. After finishing his legal studies for the day, Tycho would wait until his tutor went to bed and then would turn to his favorite subjects, astronomy and mathematics. Sometimes he would stay up almost the whole night studying these subjects. When Tycho was nineteen years old, his uncle died and left him a large fortune, after which he was free to do as he wished.

Tycho was an impulsive, superstitious, and arrogant young man, who indulged in all manner of eccentricities and often played wild jokes on his companions. While studying at Rostock, he wished to make a name for himself and so thought up a strange hoax. Tycho heard about the death of a sultan in Turkey; but because the news had been little publicized, apparently no one else in town knew of the sultan's death. Tycho also knew that an eclipse of the moon was about to occur and prophesied that the eclipse would cause the death of a Turkish sultan. News of the sultan's death spread only after the eclipse had occurred. No astrologer had ever managed to make such a precise prediction, and Tycho, therefore, was greatly revered until the day when the subterfuge was discovered. Soon afterward he had his nose cut off in a duel with another student and for the rest of his life wore an artificial nose made of gold and silver.

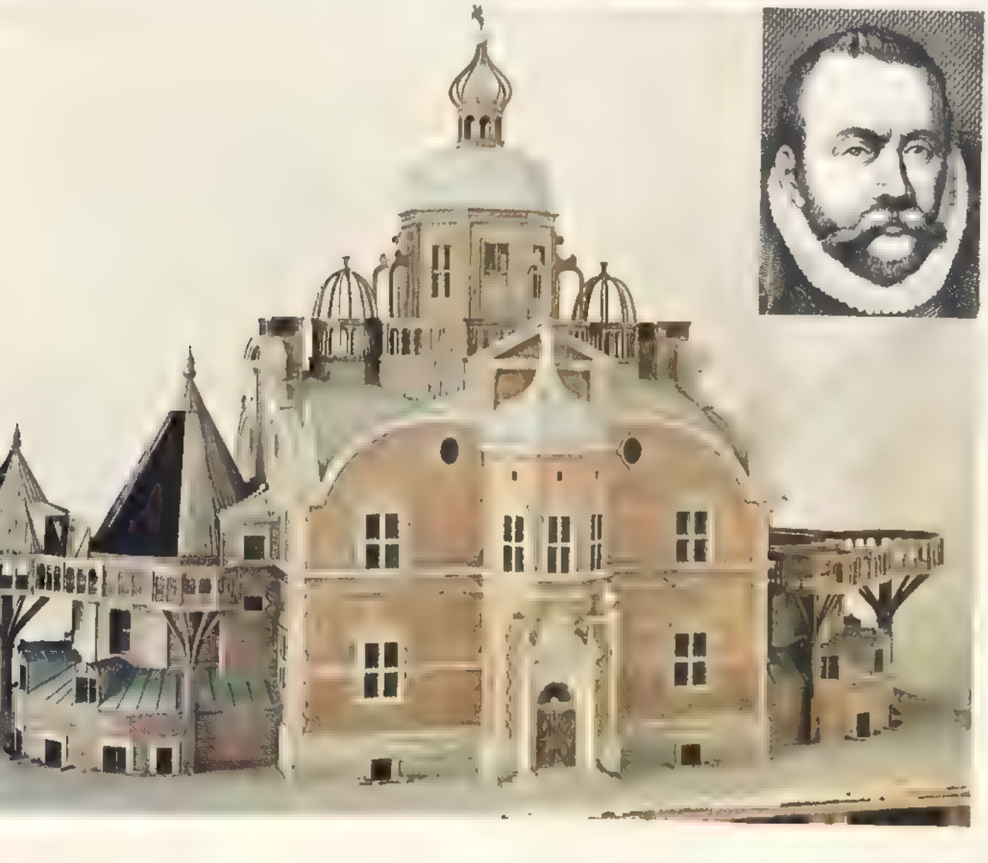
In 1571 Tycho set up a laboratory in his uncle's castle near Knudstrup. There on November 11, 1572, he witnessed the flaring out of a "new star," which until it exploded had been invisible to the naked eye. He recorded his observations on the "new star" in his book *De Nova Stella.* In addition to making Tycho famous, the book gave the name nova to all exploding stars and presented evidence, by means of parallax measurements, that the new star was farther away than the moon. This was in direct opposition to the Aristotelian notion that the universe was perfect and unchanging.

After Tycho rose to prominence, King Frederick II of Denmark became Tycho's patron and assisted him financially in establishing an observatory on the island of Hven. Estimates place the cost of the observatory and the instruments at about \$1.5 million in modern money.

In 1557 Tycho observed a large comet and concluded that not only was it farther away than the moon but that it had an elongated orbit and therefore passed through the planetary spheres. This had to mean that the planetary sphere proposed by the ancient astronomers did not exist. Tycho, however, favored the Ptolemaic system, which placed the Earth at the center of the universe. He rejected the theory of Copernicus that the Earth revolves about the sun. As a compromise explanation for his observations regarding the comet, Tycho proposed that all the planets except Earth revolve around the sun.

Tycho carried on his work at the Hven observatory until 1596, when Christian IV was crowned king of Denmark. Tycho was noted for his arrogance and extravagance, and Christian IV was far less tolerant of the flamboyant astronomer than Frederick II had been and put an end to his pensions.

The Uranienborg Observatory on the island of Hven, near Copenhagen, provided Tycho Brahe not only with working space and grand instruments but also with living quarters. It was founded in 1576 at the behest of King Frederick II of Denmark in appreciation of Brahe's work and was one of the forerunners of the great modern observatories.



In 1597 Tycho went to Germany and in 1599 settled in Prague, where he received a castle and a pension from Emperor R...olph II. While in Prague, Tycho w... assisted by Johannes Kepler. In spite ... all the advantages granted him in ... many, Tycho accomplished very litt... ore and died a few years later in ... ue.

BRATTAI... ALTER HOUSER (1902–

A disti... ing feature of the present period in ... story of science and technology is ... lthough genius is still essential fo... damental discoveries, a growing n... r of discoveries and inventions a... ne product of collective rather tha... dividual research. Moreover, it w... often be impossible to carry out s... collective research without the fi... ial backing of powerful research org... zations, such as large universities, m... ry or governmental laboratories, or ... se attached to important industrial fi... These circumstances and new proce... s in science and technology are e... nt, for example, in the career of W... r Brattain, who, together with physi... William Bradford Shockley and Jo... rdeen, made a discovery in the fie... solid-state physics that revolution... lectronics: the transistor. (*See* John ... deen; William Bradford Shockley.)

Brattain ... born in Amoy, China, of American ... eer stock. His father had moved th... mporarily to teach in a private sc... for Chinese children. The year follow... Brattain's birth the family returned t... United States and settled in the stat... Washington.

Raised in a rural environment, Brattain learned to ride at an early age and developed a love for fishing and hunting. School vacations were spent helping with chores around his father's cattle ranch.

After high school he entered Whitman College, Walla Walla, Washington, where he majored in physics and mathematics. Upon graduating in 1924, he continued with his studies in physics and received a master's from the University of Oregon in 1926 and a doctorate from the University of Minnesota in 1929.

Thereupon he worked for the radio section of the National Bureau of Standards in Washington, D.C. Although there was much important research going on, at least in certain fields, he left after only a year to join the staff of the Bell Telephone Laboratories as a research physicist. It was there that Brattain met his future collaborators and started the studies that were to bring him fame. He remained with those laboratories until 1967, when he returned to Whitman College as a professor of physics.

Initially, Brattain could not foresee that his research would one day lead to a replacement for thermionic vacuum tubes and give a new impetus to electronic technology. His chief field of research was the surface properties of solids, especially the behavior of these substances under various conditions.

The invention of the transistor in December 1947 was a result of a combination of theoretical and experimental investigations into the properties of semiconductors, solids that are intermediate in electric conductivity between metals and insulators. In 1946 Brattain, with Shockley and Bardeen, had embarked upon a research program aimed at developing a semiconductor device for electronic amplification. The first studies were concerned with rectification—the conversion of alternating current into direct current—at the surface of cuprous oxide. Similar studies of silicon followed. The first discovery was that of the photoelectric effect at the free surface of a semiconductor. The additional discovery that the electric charges moving in a semiconductor could be influenced by an electric field applied from outside marked the birth of the transistor. The practical results, however, remained negligible until a germanium diode immersed in an electrolyte was adopted for the experiments, making it possible to carry a part of the current to be controlled to the surface. Once a method had been found for treating the germanium in such a way that, in a thin layer of this material, the flow of current between two electrodes could be controlled by a third electrode, the discovery of the transistor was complete.

Walter Brattain

The discovery was communicated to the scientific world in 1948 and was immediately developed for commercial purposes. The Bell Telephone Companies lost no time in using the transistor as an amplifier in telephone lines and as a substitute for relays in switched telephone lines. Because of its small size, its ability to operate at low voltage, and its low consumption of energy, this apparatus was soon used for many different functions.

Brattain did not limit his activities to research on semiconductors and the invention of the transistor. He also perfected his studies on the impact of electrons against atoms of gaseous mercury, which had been the subject of his doctoral dissertation. In addition, he studied frequency standards, using piezoelectric quartz crystals, magnetometers, and infrared detectors and did much research on the electrochemistry of the blood. During World War II he worked on the magnetic detection of submarines for the National Defense Research Committee.

For their achievement Brattain and his collaborators received many honors and tokens of recognition: honorary degrees, election to academies, prizes, and medals, such as the Stuart Ballantine Medal of the Franklin Institute (1952) and the John Scott Medal (1955). When, together with Bardeen and Shockley, he was awarded the 1956 Nobel Prize in physics, Brattain modestly observed that he owed his success to the fact that he had been "in the right place, at the right time, and with the right kind of colleagues."

BRAUN, KARL FERDINAND (1850–1918)

Some of the later developments in the fields of radio and television were based on the research of the German physicist Karl Ferdinand Braun. For his contributions toward the improvement of wireless telegraphy, he shared the 1909 Nobel Prize in physics with Guglielmo Marconi. (*See* Guglielmo Marconi.)

Braun improved on Marconi's transmitting system by developing a method for increasing the power of the transmitting station. He did this by introducing a sparkless antenna circuit. Instead of the antenna's being directly in the power circuit, the power was coupled magnetically to the antenna circuit by a transformer effect. The principle was later applied to radio, radar, and television transmissions.

Braun was born at Fulda, Germany, and educated at the universities of Marburg and Berlin. After receiving his doctorate from the University of Berlin in 1872, he was associated with institutions at Würzburg, Leipzig, Marburg, Karlsruhe, and Tübingen, where he helped found the Physical Institute. In 1895 he became a professor of physics and director of the Physical Institute at the University of Strasbourg.

In studying mineral metal sulfides, Braun discovered that some of the crystals transmitted better in one direction than in another. This discovery later found application in crystal-set radios and, many years later, in solid-state systems.

Karl Braun

The oscilloscope, or Braun tube, was introduced by Braun in 1897. He modified the cathode-ray tube in such a way that the electrons would shift in relation to the electromagnetic field created by a varying current. The oscilloscope was used to study subtle variations in electric currents, but also, as later events proved, it was the first step toward the development of television.

At the outbreak of World War I he was in the United States on business regarding patent litigation. The U.S. authorities detained him in New York City as an enemy alien, and he died there before the conclusion of the war.

BRAUN, WERNHER VON (1912–)

The first operational guided ballistic missile and the first guided antiaircraft missile were developed in Germany under the direction of Wernher von Braun, rocket engineer and space-flight proponent. Later, in the United States, Braun developed the space-launch vehicles that put the first U.S. satellite into orbit and carried men to the moon.

Braun was born at Wirsitz, Germany, and educated in Zürich, Switzerland, and Berlin, Germany. His boyhood interest in astronomy and space flight led to his joining in 1930 the German Society for Space Travel. He became involved in the group's experiments with small liquid-fueled rocket engines. After receiving his bachelor's degree in mechanical engineering from the University of Berlin in 1932, he accepted a research grant from the German Ordnance Department that enabled him to expand his investigations into rocketry.

In 1934, the same year that he received his doctorate, the German Ordnance Department employed Braun as a rocket-development engineer. The successful program that followed resulted in his appointment as technical director of the army portion of the Rocket Center at Peenemünde, a joint enterprise of the German army and air force. Under his leadership the first true missile, carrying its own fuel and oxygen, was shot off in 1942. It was the devastating V-2, which was put into combat use in 1944. About 4,300 V-2s were fired during World War II.

Toward the close of the war, Braun led more than 100 of his associates to surrender to the Western Allies. In September 1945 Braun and his colleagues went to the United States under contract to the U.S. Army. Braun directed high-altitude firings of captured V-2 rockets at the White Sands Missile Range in New Mexico and became project director of guided-missile development at Fort Bliss, Texas. In 1950 Braun and his team from Peenemünde became the nucleus of the U.S. Army ballistic-weapons program at Huntsville, Alabama, where the Redstone, Jupiter-C, Jupiter, Juno, and Pershing missiles were developed. During the 1950s Braun was a focus for professional interest in space flight, but public support lagged until the U.S.S.R. Sputnik I was launched in October 1957. Given approval to proceed, Braun and his associates placed the first U.S. satellite, Explorer I, in orbit in January 1958.

After World War II, Wernher von Braun (right), became one of the foremost space experts in the United States. He and his colleagues placed the first U.S. satellite, Explorer I, in orbit in 1958 and provided the Saturn launch vehicles for the Apollo lunar program, which culminated in the moon landing of 1969.

In 1960 Braun and his group were transferred to the National Aeronautics and Space Administration (NASA) and became the core of the George C. Marshall Space Flight Center. As such they had the responsibility for providing the Saturn launch vehicles for the Apollo lunar program. Saturn V carried men to the moon in July 1969. The following year Braun received an appointment to serve as NASA's deputy associate administrator for planning.

Braun, who became a U.S. citizen in 1955, received the Smithsonian Institution Langley Medal, many professional awards, and honorary doctorates. He wrote or coauthored *Across the Space Frontier* (1952), *Conquest of the Moon* (1953), *The Mars Project* (1953), *Exploration of Mars* (1956), *First Men to the Moon* (1960), *History of Rocketry and Space Travel* (1967), and *Space Frontier* (1967).

BRIDGMAN, PERCY WILLIAMS (1882–1961)

Before the U.S. physicist Percy Williams Bridgman began his research, knowledge about the nature of materials under high-pressure conditions was limited because of the inability of existing equipment to withstand pressure above 3,000 atmospheres. Bridgman invented equipment that would hold up under extremely high pressures and developed high-pressure research techniques. With these new tools, he investigated various properties of matter under extreme pressure, including electrical and thermal conductivity, compressibility, tensile strength, and changes in the viscosity of liquids. For his research on high pressure Bridgman won the 1946 Nobel Prize in physics.

He was born at Cambridge, Massachusetts, and educated at Harvard University. His entire career, from the time he received his doctorate in 1908 until he retired in 1954, was associated with Harvard. In 1910 he became an instructor in physics there; in 1919, an assistant professor; and in 1926, a professor of mathematics and natural philosophy.

Bridgman's interest in high-pressure research began during his years as a student. A major fault in high-pressure equipment was that the seals would break at about 3,000 atmospheres. For his apparatus Bridgman invented a self-tightening joint that would seal itself more securely as the pressure was increased. He constantly modified the design of his equipment and eventually

Percy Bridgman

Using the [illegible]ment that he invented for withstanding [illegible]mely high pressures, Percy Bridgman [illegible]ucted extensive research on the prope[illegible] more than 100 compounds at pressures [illegible]00 atmospheres or more. His work was [illegible]mportant in the development of indust[illegible] [illegible]onds.

could produce pressure of up to 100,000 atmospheres, and, in a rare number of cases, 450,000 atmospheres.

In his research he identified seven different types of ice and discovered two new forms of phosphorus. He consulted with the General Electric researchers who, in 1955, first synthesized industrial diamonds from graphite under high pressure and high temperature. Bridgman's high-pressure research lent a new understanding of the materials and processes deep within the Earth. He also wrote extensively on the philosophy of science.

In 1949 he was elected a foreign member of the Royal Society. He was also a member of the American Academy of Arts and Sciences. Among the other honors accorded him were the Rumford Medal, the Comstock Prize, the medal of the Dutch Royal Academy, and numerous honorary degrees from foreign and U.S. universities. At the age of seventy-nine, being ill with an incurable disease, Bridgman committed suicide.

BROGLIE. See De Broglie, Prince Louis Victor Pierre Raymond.

BROWN, ROBERT (1773–1858)

Scottish-born Robert Brown, the foremost botanist of the early nineteenth century, was the first to describe the cell nucleus in plants and the first to make a microscopic investigation of what came to be known as Brownian movement—the constant random motion of small particles in matter suspended in a liquid or gas. This phenomenon eventually was explained by the kinetic theory of gases.

In 1827, while he was using the microscope to study pollen suspended in water, Brown noticed that the grains were zigzagging. He learned that the movement was not a result of life in the particles; the pollen of long-dead plants acted the same way, and so did such nonliving bodies as minerals. Subsequent scientific research revealed that the erratic movements result when molecules of the gas or liquid bombard the particles in suspension.

Brown, whose lifework expanded understanding of the sexual process in higher plants, was the first to distinguish between angiosperms and gymnosperms. He also initiated microscopic study of fossil plants.

Brown was born in Montrose, Angus, Scotland, and educated there and at Marischal College in Aberdeen. He began the study of medicine at Edinburgh in 1789, but he did not take a medical degree. While serving in the army as a medical officer, Brown collected plants as a hobby. During a tour of duty in Ireland, he met Sir Joseph Banks, English explorer, naturalist, and patron of science. In 1800, on Banks's recommendation, Brown was offered the post of naturalist to the expedition of Captain Matthew Flinders, who planned to survey the coast of Australia. Brown and Flinders began their survey of the almost unknown coast in 1801. When they returned to England in 1805, they brought with them almost 4,000 species of plants—many new to botanists.

Brown was faced with special problems in classifying the plants that are native only to Australia because of its isolation. He classified them according to the natural system developed by Antoine Laurent de Jussieu (1748–1836), which was based on the number of embryonic leaves. Brown's solutions had great influence on the science of taxonomy.

In his research Brown found the small body that he saw within the cells of plant tissue to be a regular component of the cells. In 1831 he gave it the name cell nucleus, by which it still is known.

In 1810 Brown published the first volume of what was to be a comprehensive work, *Podromus florae novae Hollandiae et insulae Van Diemen,* which promoted the adoption of a system for classifying plants according to structure and appearance. Except for a supplement published in 1830, however, no more of the work appeared.

Brown became librarian-botanist to Banks in 1810. On his death in 1820, Banks bequeathed the use of his library and collections to Brown for life. Brown transferred them to the British Museum in 1827 and took charge of the museum's botanical collections until his death.

BRUNEL, SIR MARC ISAMBARD (1769–1849) **and**
ISAMBARD KINGDOM (1806–1859)

A father and son who practiced engineering in England during the first half of the nineteenth century are remembered for their remarkable inventiveness and versatility. The father, Sir Marc Isambard Brunel, is best known as a pioneer of mass production, designer of the first tunneling shield, and builder of the first underwater tunnel. His only son, Isambard Kingdom Brunel, designed the first transatlantic steamship.

The elder Brunel was born in Hacqueville, Normandy, France. He served as an officer in the French navy from 1786 to 1792, but his royalist sympathies led him to flee revolutionary France in 1793 and work for a time as an architect and engineer in the United States. In 1799 he sailed to England to present his ideas for mass production of ships' blocks, or pulleys, which the British Admiralty required in large numbers. After laying his plans before the British government, Brunel was engaged to oversee the erection of his machines at Portsmouth dockyard. Driven by thirty-horsepower engines, forty-three machines converted elm logs into blocks ready for fitting and polishing. Only 10 unskilled men were needed to do what 110 skilled men had done without Brunel's machines.

A prolific inventor, M. I. Brunel designed machines for sawing and bending timber, knitting stockings, making boots, and printing. The government, which had encouraged Brunel to equip a factory for making army boots, refused to

accept the output when the Napoleonic Wars ended in 1815. This and other financial reverses led to Brunel's imprisonment for debt in 1821, but his friends obtained a grant of £5,000 from the government for his release. Through his next undertaking, Brunel rose from his state of embarrassment to the heady honor of knighthood.

In 1825 M. I. Brunel began to build at Rotherhithe the first Thames River tunnel. Some say that he got the idea for his iron tunneling shield while watching a shipworm at work. Brunel tunneled with the aid of a shield consisting of twelve cast-iron frames, each twenty-two feet high and three feet wide and divided by platforms into three tiers. Thirty-six men could work in the shield. As excavation proceeded, sections of the shield were advanced alternately by means of jackscrews, and a brick lining was placed immediately behind. Accidental flooding delayed the work several times, and the tunnel was not completed until 1843. Brunel was knighted in 1841 for his accomplishment.

The younger Brunel was born at Portsmouth, England; and he was educated at public schools in England and at the Lycée Henri Quatre in Paris, France. He went to work with his father in 1823 and became resident engineer on the Thames Tunnel. He held that post until 1828, when a sudden flooding injured him seriously and halted the work for seven years. Later, while making improvements in the Bristol docks, he met the promoters of the Great Western Railway, which extended from London to Bristol. In 1833, at the age of twenty-seven, he was made chief engineer of the company.

On the railway's main line from Paddington to Bristol, Brunel introduced the broad (seven-foot) gauge. It was both controversial and a commercial failure, but the high speeds that it made possible stimulated railway progress. Brunel was responsible for building more than 1,000 miles of railway in the West Country and Midlands of England, in Ireland, and in south Wales. In building the Chepstow Railway Bridge in 1852, he initiated use of a compressed-air caisson to erect one of the main bridge towers in the riverbed.

A change from his transportation engineering was the completely prefabricated hospital building that he designed. It was shipped in parts to the Crimea for use in the Crimean War (1854–1856).

The contributions of I. K. Brunel to marine engineering were his three ships, *Great Western* (1837), *Great Britain* (1843), and *Great Eastern* (1858). Each was the world's largest ship at the time of its launching. The first, a wooden paddle steamer, was the first successful transatlantic steamship. It made the crossing in fifteen days. The second was the first large iron-hulled screw-driven steamer. The third, propelled by both paddles and screw, had a double iron hull. It was the prototype of the modern ocean liner, and its size was not exceeded for forty years.

Construction and launching of the *Great Eastern* involved financial and technical difficulties that helped wear down the health of its designer, and he died of a stroke before it was actually set afloat. The *Great Eastern* had the distinction of laying the first successful transatlantic cable.

BUCHNER, EDUARD (1860–1917)

For his research into fermentation and other enzyme action, the German chemist Eduard Buchner won the 1907 Nobel Prize in chemistry. His work pointed the way to modern enzyme chemistry.

In 1897 Buchner demonstrated that the action of enzymes contained in yeast—and not the yeast cell itself—is the active cause of alcoholic fermentation. This discovery contradicted the belief of the vitalists—scientists, including Louis Pasteur, who maintained that chemical changes by enzymes (nonliving chemical substances) can take place only within living cells. Buchner ground up yeast cells with sand, prepared a cell-free extract, and mixed it with sugar. The sugar was changed into carbon dioxide and alcohol by the extract, just as it is by whole and living yeast.

Buchner was born in Munich, Germany. His interest in chemistry was whetted by his older brother Hans, a prominent bacteriologist. Eduard studied at the University of Munich with Johann von Baeyer, another Nobel laureate. He served as Von Baeyer's assistant until 1893 and then held a series of professorships in Kiel, Berlin, Breslau, and Würzburg.

Buchner served as a major in the German army during World War I. He died of grenade wounds incurred on the Rumanian front.

BUFFON, GEORGES LOUIS LECLERC, COMTE DE (1707–1788)

The first modern attempt to cover all scientific knowledge was undertaken by Georges Louis Leclerc, Comte de Buffon, an eighteenth-century French naturalist. His *Histoire naturelle générale et particulière* was published in forty-four large volumes over a period of more than fifty years. It was clearly written and widely read.

Buffon was born at Montbard, Côte d'Or. He received a law degree in 1726 from the Jesuit College at Dijon, where his father was a magistrate and a councillor in the Burgundian Parliament, and went on to study medicine at Angers.

His interest in botany and [illegible]sire to master the English language [illegible] him to publish a French translation [illegible]tephen Hale's *Vegetable Statistics* [illegible]35 and

Georges Leclerc, Comte de Buffon

In the section "On Man" in Geor[illegible] Buffon's *Histoire naturelle*, there is an illus[illegible]tion of a young South American mulatto [illegible]tion believed that the patches on the ch[illegible] skin resulted from the crossing of the bl[illegible]nd white races. Despite such absurdities, h[illegible]or work had, in general, great merit.

of Sir Isaac Newton's *Fluxions*, a book on calculus, in 1740. The Royal Society of London made Buffon a member in 1739.

At about the same time, when he was only thirty-two years old, Buffon was appointed [illegible] of the Jardin du Roi, the French [illegible]nical gardens, and of the museum th[illegible] was a part of it. He was given the [illegible] through the patronage of the French [illegible] of marines, J. F. P. de Maurep[illegible] the forests of the family estate in B[illegible]ndy, Buffon had studied the proper[illegible] and improvement of timber. Maure[illegible] was eager to apply Buffon's know[illegible] to the government's shipbuildin[illegible] projects. Maurepas also asked Buff[illegible] write a catalog of the museum's c[illegible]tion, and it was this assignment th[illegible] Buffon expanded to encompass all [illegible] was known of natural history at th[illegible] time.

The *Histo[illegible] naturelle* passed through several edit[illegible] and was translated into many langu[illegible] Collectors prize the first edition, pu[illegible] between 1749 and 1804, becau[illegible] the beauty of its engraved plate[illegible] Buffon had several distinguished [illegible]borators, and the last eight volu[illegible] were finished after his death.

Buffon w[illegible] elected to membership in the leadin[illegible] academies and learned societies of [illegible] He was made a count by King Lo[illegible] of France.

BUNSEN, R[illegible] WILHELM (1811–189[illegible]

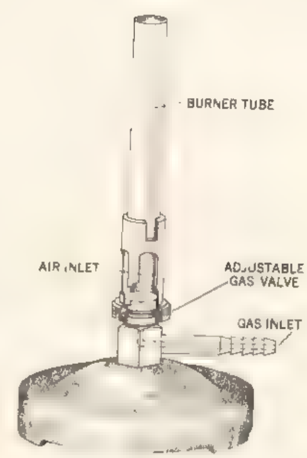
His part i[illegible] invention of the Bunsen burner mad[illegible] name of Robert Wilhelm Buns[illegible] household word, even to the present day. It was in the field of chemical spectroscopy, however, that Bunsen made his greatest contribution to science. Along with G. R. Kirchhoff he invented the technique of chemical spectroscopy in 1860. Through spectrum analysis he discovered two new elements of the alkali group, cesium and rubidium. (*See* Gustav Robert Kirchhoff.)

Bunsen was born at Göttingen, Germany, and educated at the University of Göttingen, from which he received his doctorate in 1830. After traveling throughout France and Germany, he taught at universities in Göttingen, Kassel, Marburg, and Breslau. In 1852 he was appointed to the chair of chemistry at the University of Heidelberg, where he remained until shortly before his death. Bunsen never married, his life being entirely bound up in his work. In research his greatest interest lay in performing practical experiments.

His first significant research was done on organic compounds containing arsenic (cacodyl compounds). The work was extremely dangerous, and, in 1836, he lost an eye as a result of an explosion. Also, he nearly died of arsenic poisoning because of the slow absorption of the deadly substance into his body during the course of the work. After completing the research, he never worked in organic chemistry again and would not even allow the subject to be studied in his laboratory at Heidelberg.

Bunsen's only significant work in industrial chemistry involved studies of blast-furnace gases. This research led to the development of his method for measuring gaseous volumes. His only book, *Gasometrische Methoden*, published in 1857, was devoted to this subject.

The list of Bunsen's accomplishments is considerable. In 1841 he invented a carbon-zinc electric cell and used it to produce an electric arc. He developed the grease-spot photometer in 1844. Also, he invented the filter pump, the ice calorimeter, and the vapor calorimeter.



Robert Bunsen's idea of mixing air and gas to produce a hot, nonluminous flame is still applied in the construction of millions of burners to be used for heating and lighting.

His interest in measuring heat led him to investigate geysers in Iceland in 1846. Bunsen was the first to isolate metallic magnesium and study its properties. He demonstrated the brilliance of the magnesium flame when burned in air. This subsequently became important in photography. He worked with Sir Henry Enfield Roscoe on photochemical measurements, and together they formulated the reciprocity law.

BURBANK, LUTHER (1849–1926)

One of the world's greatest horticulturalists, Luther Burbank did much to encourage experimental and creative plant breeding in the United States. Over the years he developed, by cross-breeding and by grafting, more than 800 new varieties of plants, encompassing about 200 genera. These included 90 varieties of vegetables, 60 varieties of plum, and 10 varieties of berry for commercial production.

Burbank, born in Lancaster, Massachusetts, acquired only the equivalent of a high-school education. He attended public schools and spent some time at the Lancaster Academy. Nevertheless, even as a child he showed interest in garden-

The type of s[illegible]roscope used by Robert Bunsen and the [illegible]erman physicist Gustav R. Kirchhoff in their work on spectrum analysis makes it possible to view the dark lines of the solar spectrum and to examine the elements of distant stars.

ing and had a talent for observing subtle differences in plants. At the Lancaster library he found Charles Darwin's *Variation of Animals and Plants Under Domestication* and went on to read other scientific books by Darwin and other authors.

Luther Burbank

In 1870, when he was twenty-one, Burbank bought a seventeen-acre plot of land near Lunenberg, Massachusetts. There he began his plant-breeding work and in 1873 developed the famous Burbank potato. This potato was eventually introduced into Ireland in an effort to avoid a recurrence of such a blight as had occurred there in the 1840s. He sold his rights to the Burbank potato for $150 and, following the lead of his three older brothers, in 1875 moved to California.

He settled down in Santa Rosa and established a nursery and greenhouse, which in time became famous throughout the world. For fifty years he remained there, developing many new varieties of fruits, vegetables, grains, grasses, and flowers. Among Burbank's best-known varieties of flowers are the fire poppy, the Burbank rose, and the Shasta daisy. One of his most famous experiments involved the breeding of spineless cacti for forage.

The aim of Burbank's work was solely to create better and more productive varieties of plants. He was not concerned with proving any scientific theory. It was not until late in life that Burbank heard of the work done by Gregor Mendel, but even then he did not believe that characteristics are determined by genes. Instead, he subscribed to the erroneous theory that acquired characteristics can be passed on. He lectured on this topic at Stanford University, Palo Alto, California.

The great naturalist was also a prolific writer. His works include *Luther Burbank, His Methods and Discoveries* in twelve volumes, *How Plants Are Trained to Work for Man* in eight volumes, and an autobiography written with Wilbur Hall called *Harvest of the Years*.

BURNET, SIR FRANK MACFARLANE (1899–   )

For the discovery of acquired immunological tolerance to tissue transplants the Australian physician-virologist Sir Frank MacFarlane Burnet shared the 1960 Nobel Prize in physiology or medicine with P. B. Medawar. Burnet predicted that the tolerance could be established experimentally, and Medawar's group proved it. (*See* Peter Brian Medawar.)

Burnet also developed methods for virus propagation in chick embryos and methods for identifying bacteria by the bacteriophages—bacteriolytic viruses—that attack them. His virus researches increased the understanding of how influenza viruses cause infection.

Burnet was born in Traralgon, Victoria, Australia, and studied at Geelong College and Melbourne University, where he received his medical degree in 1923. He worked as a research fellow at Lister Institute in London, England, from 1926 to 1927. In the following year he became assistant director of Hall Institute for Medical Research at Melbourne Hospital. In 1944 he was named director of the Hall Institute and professor of experimental medicine at Melbourne University.

Sir Frank Burnet

For his accomplishments, Burnet was elected to membership in the Royal Society of London in 1942 and was awarded its Royal Medal in 1947 and its Copley Medal in 1959. In 1954 he was elected a foreign associate of the United States National Academy of Sciences. He was knighted in 1951 and received the Order of Merit in 1958.

BUTENANDT, ADOLF FRIEDRICH JOHANN (1903–   )

The German biochemist Adolf Butenandt devoted most of his career to research on human sex hormones. He succeeded in isolating and identifying the structures of these hormones and studied the relationship of different hormones to each other. It was mainly because of his work on hormones that the large-scale production of cortisone became possible. For his contributions in this area of science, Butenandt shared the 1939 Nobel Prize in chemistry with Leopold Ruzicka. The Nazi regime, however, forced Butenandt to refuse the award, and it was not until 1949 that he was able to accept it. (*See* Leopold Ruzicka.)

Butenandt's first major discovery came in 1929 when he isolated the female hormone estrone from the urine of pregnant women. This hormone is responsible for sexual development in women. He made this discovery almost simultaneously with Edward Adelbert Doisy.

In 1931 he found androsterone, the hormone responsible for male sexual development. Butenandt's analysis of the structure of androsterone made it possible for Ruzicka to synthesize this male hormone within a few years.

In 1934 Butenandt isolated another female hormone, progesterone, which is important in the chemical changes that take place during pregnancy. In addition to his work with human sex hormones, Butenandt, together with Peter Karlson, isolated the first crystalline insect hormone, ecdysone. It was recognized through prior investigations by others as a close relative of the sex hormones. He also did research on pheromones and had a special interest in the study of viruses.

Butenandt was born at Bremerhaven-Lehe, Germany. He studied biology and chemistry at the universities of Marburg and Göttingen. In 1927 he received his doctorate from Göttingen and began working as an assistant at the university's Chemical Institute. Three years later he became director of the organic chemical laboratories at Göttingen.

From 1933 to 1936 he was an associate professor of chemistry at the Technical Institute of the Free State of Danzig. In 1936 he was appointed director of the Kaiser Wilhelm (later renamed Max Planck) Institute for Biochemistry in Berlin. After World War II he taught at the University of Tübingen, and in 1956 he became professor of physiological chemistry at the University of Munich. He was elected president of the Max Planck Society in 1960.

BYRD, RICHARD EVELYN (1888–1957)

The famous American explorer Richard Evelyn Byrd not only distinguished himself by making unprecedented polar expeditions but also pioneered in the field of aviation. Byrd is universally regarded as the foremost Antarctic explorer of the second quarter of the twentieth century, having made five separate expeditions to the desolate and uninhabited continent. He was the first to fly over the North Pole and later the South Pole. He also made daring transatlantic flights.

Byrd's adventurous spirit exhibited itself early in life, for when he was only twelve years old he made an unaccompanied trip around the world. He was born at Winchester, Virginia, and educated at military schools, the University of Virginia, at Charlottesville, and the United States Naval Academy, at Annapolis, Maryland. After graduation in 1912, he was commissioned as an ensign and saw three years of active service before being retired because of leg injuries sustained in sports activities at Annapolis. During World War I, however, he reentered the navy and became a pilot. From July to November 1918, he commanded U.S. air forces in Canada.

Throughout his life Byrd was interested in aviation and did much to promote the development of naval aviation reserves. He also aided Charles Lindbergh with preparations for his historic transatlantic flight. In 1921 Byrd made a transatlantic flight in a dirigible, and in 1927, along with three companions, he flew from New York to Paris with the first official air mail service between those points. A dense fog prevented them from landing at Paris, and they were forced to ditch the plane in the ocean.

The polar career that was to ensure Byrd's fame began in 1924 when he took command of the naval aviation detachment on an Arctic expedition to western Greenland. Events surrounding this expedition led Byrd to organize a private Arctic expedition and transport his plane, the *Josephine Ford*, to Kings Bay, Spitsbergen. On May 9, 1926, with Floyd Bennett as his pilot, Byrd flew over the North Pole. This event won him international fame, a promotion to the rank of commander in the navy, and support for his planned Antarctic expedition.

In 1928 he arrived with forty-two men in Antarctica and established Little America. On November 29, 1929, he and three others flew over the South Pole. In recognition of his achievement, he was made a rear admiral. On the first Antarctic trip, he discovered the Rockefeller and Edsel Ford mountains and Marie Byrd Land, named in honor of his wife.

His second expedition to Antarctica was in 1933–1935. During the winter of 1934, he spent five months alone at an outpost 123 miles south of the expedition's main base. This was the farthest south that man had ever survived for any period of time. In his small hut Byrd almost died from carbon monoxide fumes caused by a defective stove. The three other trips to Antarctica were all made during the summer seasons.

Just prior to World War II, Byrd was in command of the U.S. Antarctic service. During the war he served on the staff of the chief of naval operations, evaluating Pacific islands as operational bases. After the war he resumed his Antarctic explorations and served as officer in charge of a 4,000-man operation, the objective being to take aerial photographs of the Antarctic coast.

As officer in charge of U.S. Antarctic programs, he made his last Antarctic expedition in 1955–1956 when he was well over sixty-five years of age. Soon after his return, he died in Boston, Massachusetts, and was buried with full honors at Arlington National Cemetery.

On his second expedition to Antarctica (1933–1935) Richard Byrd spent the winter of 1934 alone in a small hut, miles from the expedition's main base. During subsequent Antarctic trips, as director of U.S. government expeditions, he continued exploring by plane.

CAJAL. See Ramon y Cajal, Santiago.

CALVIN, MELVIN (1911–)

The U.S. chemist Melvin Calvin was awarded the 1961 Nobel Prize in chemistry for his research into photosynthesis. He traced the processes whereby green plants convert stored light energy, carbon dioxide, and water into the thousands of compounds necessary for their growth. His achievement was particularly significant because all life on Earth ultimately depends upon the food and oxygen provided by plants.

Melvin Calvin

Calvin was born at St. Paul, Minnesota. He received his bachelor's at Michigan College of Mining and Technology in 1931 and his doctorate in chemistry at the University of Minnesota in 1935. The next two years he spent at the University of Manchester in England as a fellow of the Rockefeller Foundation. In 1937 he joined the faculty of the University of California at Berkeley as an instructor. He was appointed to a full professorship in 1947.

Calvin was named a director of the bio-organic chemistry group in the university's Lawrence Radiation Laboratory. The group became the Laboratory of Chemical Biodynamics in 1960. Calvin was elected to the National Academy of Sciences in 1954 and to the Royal Society of London. In 1964 he was the winner of the society's Davy Medal, which is given annually for the most important discovery in chemistry made in Europe, Canada, and the United States.

CANDOLLE, DE, FAMILY

In the eighteenth and nineteenth centuries the Candolle family, three generations of Swiss botanists, worked toward the development of a natural system of classification of flowering plants. This monumental work was begun by the most famous member of the family, Augustin Pyrame de Candolle (1778–1841), and was later continued by his son and his grandson.

The elder Candolle was born and educated at Geneva, Switzerland. Earlier his family had fled from France to Switzerland to avoid religious persecution. In 1796 he moved to Paris and began his life's work on developing a natural system of plant classification.

His first major work, *Plantarum succulentarum historia* (1799–1829), attracted the notice of the French naturalists Georges Cuvier and Jean Baptiste Lamarck, who entrusted him with the publication of the third edition of *Flore Française* (1803–1815). The introduction to this edition contained the first exposition of Candolle's natural system of plant classification.

It was Candolle who, in 1813, introduced the word *taxonomy* to describe the science of classification. He held that the only basis of taxonomy was morphology, and he developed a theory of plant symmetry. His system of classification was based on that of A. L. de Jussieu, employing three main groups: dicotyledons, monocotyledons, and acotyledons.

During the summers from 1806 to 1812, he conducted a botanical and agricultural survey of France for the French government. The results of this survey were published in 1813. He was appointed professor of botany at the University of Montpellier in 1808. In 1816 he returned to Geneva and became professor of natural history. At Geneva he established the Conservatoire Botanique and Botanical Garden.

Augustin Pyrame de Candolle

In 1824 he began his best-known work, *Prodromus systematis naturalis regni vegetabilis*, in which he attempted to present a complete natural system of plant classification. He was able to finish only seven volumes, however, before his death.

His son Alphonse Louis Pierre Pyrame de Candolle (1806–1893), born in Paris, succeeded him as professor of natural history at Geneva in 1842. The younger Candolle was famous in his own right for developing the laws of botanical nomenclature. He also conducted studies on the origin of cultivated plants.

Alphonse took up the work of his father on the natural system of plant classification. In collaboration with his son Anne Casimir Pyrame de Candolle (1836–1918), Alphonse completed the remaining nine volumes, the last being published in 1873.

CANNIZZARO, STANISLAO (1826–1910)

Chemistry and revolution both played a large part in the life of Stanislao Cannizzaro. As a revolutionary his life was colorful; as a chemist his life was most noted for his part in ending the professional confusion surrounding atomic weights and how to determine them.

Cannizzaro was born at Palermo, Sicily, and studied medicine, chemistry, and physics at the universities of Palermo, Naples, and Pisa. He temporarily abandoned his career to join the Sicilian revolution of 1848. At that time Sicily was a part of the kingdom of Naples. For his part in the insurrection he was condemned to death by the Bourbon rulers. When the revolution failed, he fled to France and resumed his work in chemistry in Paris.

In 1851 he returned to Italy and became a professor of physics and chemistry at the Technical Institute of Alessandria. In spite of a lack of laboratory space and equipment, while at Alessandria he discovered the phenomenon known as the Cannizzaro reaction. He found that in the presence of a strong alkali, aldehydes can be converted into an acid and an alcohol. Later he did research on santonin. He also held professorships in Genoa, Palermo, and Rome.

His most important work, done on atomic weights, began in 1858 when he discovered Avogadro's long disregarded hypothesis. Cannizzaro clearly defined the difference between molecular weights and atomic weights. He wrote a pamphlet explaining how the atomic weights of elements in volatile compounds can be deduced from the molecular weights of the compounds. This pamphlet he distributed at the First International Chemical Congress held at Karlsruhe, Germany, in 1860—the world's first international scientific conference. (*See* Amedeo Avogadro.)

His method for determining atomic weights soon found wide acceptance among chemists, and the fact that atomic

Scales were o[illegible]reat importance in the work of Stanislao C[illegible]zaro while he was professor of physics an[illegible]hemistry at the Technical Institute of Al[illegible]ndria from 1851 to 1855.

weights cou[illegible] determined correctly made possi[illegible]he development of the periodic sy[illegible] For his work in this area Canniz[illegible] was awarded the Copley Medal o[illegible] Royal Society.

In 1860 h[illegible] again interrupted his career to [illegible] Giuseppe Garibaldi's forces in th[illegible]ck on Naples. In 1871 Cannizzaro [illegible]ne an Italian senator and eventu[illegible] vice-president of the Senate. As [illegible]mber of the Council of Public Instr[illegible]n, he did much to further scientif[illegible]ducation in Italy.

CARDAN, JE[illegible]ME (1501–1576)

In addition to being a famous doctor, the sixteenth-century Italian physician Jerome Cardan excelled in mathematics. He also practiced and believed in astronomy, though his predictions were frequently wrong.

Cardan, the illegitimate son of a Milanese lawyer, was born Geronimo (or Girolamo) Cardano at Pavia. He was educated at the universities of Pavia, Padua, and Milan, receiving a degree in medicine from Padua in 1526. In 1532 he moved to Milan and lectured in mathematics. Although he published a book attacking the practices of the medical profession, he was admitted, with the support of influential sponsors, to the College of Physicians in 1536. In 1543 he was appointed professor of medicine at Pavia; in 1562, at Bologna.

As his fame as a physician grew, European royalty sought his services. In 1552 he traveled to Scotland to treat the archbishop for asthma. Cardan, who is credited with having an intuitive understanding of allergies, effected a cure by recommending that the archbishop not use feathers in his bed.

Cardan wrote extensively on a number of topics, including astronomy, astrology, rhetoric, and medicine. He was the first to give a clinical description of typhus fever and the first to write on the treatment of syphilis. He also had some ideas on how to teach the deaf and dumb and the blind. His *Ars magna* (1545) was the first important treatise on algebra, and he wrote the first book containing a systematic computation of probabilities. His most famous book was *De subtilitate rerum,* containing accounts of physical experiments and inventions and also some anecdotes.

For all his brilliance Cardan was a man of questionable morals. He received the method of solving cubic equations from Niccolo Tartaglia and, after promising to keep it a secret, published the method, claiming it as his own. The scandal surrounding this mathematical plagiarism raised important questions about the ethics of keeping a scientific discovery secret. It was finally decided that secrecy was harmful to the cause of science and that credit for a discovery should go to the one who first made it public, even if he was not the original discoverer.

The latter part of Cardan's life was filled with misfortune. His wife died in 1546, and he was left with three children. One son was executed in 1560 for murdering his wife; another son became a disreputable character. In 1570 Cardan, then living in Bologna, was arrested and charged with heresy. After a few months in prison he was released but lost his post at the university and also his right to publish. In 1571 he moved to Rome, where he remained until his death five years later.

CARNOT, NICOLAS LÉONARD SADI (1796–1832)

When he was a child, Sadi Carnot, the father of thermodynamics, showed great sensibility and daring one summer afternoon at the beginning of the nineteenth century when he reproved Napoleon for splashing water on the dresses of ladies who were boating. It would have been difficult, however, for anyone who heard him that day to imagine that he more than his father would pass into history and bring luster to the Carnot name.

Sadi Carnot was born in the Luxembourg Palace in Paris, the son of the great Lazare Carnot, statesman and military engineer, who, because of his services to the Revolutionary armies, was known as the Organizer of Victory.

Upon his temporary retirement from public life, the elder Carnot devoted himself to the education of his son, who seemed worthy of his father's hopes. Sadi applied himself so earnestly to his studies that he was able to prepare for the entrance exam to the École Polytechnique in a few months. After two years there, he left with highest honors and a commission in the engineers.

His career, however, became threatened by his father's political activities. Sadi was continually transferred from one fortress to another. In 1819 he was placed on the reserves and so was able to devote himself to study and meditation, dividing his time between scientific and literary pursuits.

Sadi Carnot

His study of physics and mathematics led him to the contemplation of a problem that until then had been overlooked: the relationship between heat and mechanical functioning, or motive power. Motor mechanics had already been examined but only from the standpoint of the mechanisms, such as the pistons, the distributors, the speed regulators, and the crank gears. One particular had always been neglected: the source of the energy.

To acquaint himself more fully with this problem, Carnot studied the various models of steam engines then in existence. He observed that when a gas is alternately expanded and compressed, or heated and cooled, it absorbs heat at the high temperatures and gives up heat at the low temperatures, being restored at the end of the cycle to its initial state. The net result of this process, known as the Carnot cycle, is the loss of heat by the hot body, the gain of a somewhat smaller amount of heat by the cold one, and the conversion of some of the heat into work. This cycle is applicable to all engines using heat, not only to steam

engines, and can be used to calculate the productive capacity of a jet engine, as well as that of a steam locomotive.

In 1824 Carnot published his *Reflections on the Motive Power of Heat*, the result of his observations and findings. According to this work, the efficiency of a reversible engine depends on the temperatures between which it works—the difference between the maximum and the minimum temperatures. This is known as Carnot's principle, and it is fundamental to thermodynamic physics.

In 1828 Carnot left military life for good. Unlike his father, he never took an active part in public life. His was a solitary existence. Not even the Revolution of 1830 brought him out of his self-imposed isolation. It was almost as if he was rebelling against those who had misinterpreted his father's qualities.

Weakened by scarlet fever and a brain fever, he fell an easy victim to a cholera epidemic that struck Paris in 1832. He died as alone as he had lived, without ever imagining that he had ensured immortality for the name Carnot.

CARREL, ALEXIS (1873–1944)

In 1902 the French surgeon and biologist Alexis Carrel developed a technique for suturing blood vessels end to end. For his achievement, which opened the way to advances in vascular surgery, Carrel was awarded the 1912 Nobel Prize in physiology or medicine. His method made blood transfusion safe and gave impetus to the study of organ transplantation. Earlier efforts to transplant organs had often failed because of the lack of a method for reestablishing circulation through the transplants.

Other work for which Carrel is celebrated includes the preservation and study of living tissue outside the organism, treatment of wounds to prevent gangrene, and development of a mechanical heart. Most of his professional life was spent in the United States.

Carrel was born at Sainte-Foy-lès-Lyon, France. He received his medical degree from the University of Lyon in 1900 and began his experimental researches while on the staff of its medical school. In 1905 he moved to Chicago, where he worked at the University of Chicago. He joined the staff of the Rockefeller Institute for Medical Research in New York City in 1906.

Returning to France during World War I, Carrel, with the British chemist Henry Dakin, devised a treatment for wounds by which countless amputations were avoided. The method consisted of constant irrigation with a solution of sodium hypochlorite, which was antiseptic but quite harmless to healthy tissue.

Back at the Rockefeller Institute after 1919, Carrel developed new ways of cultivating tissues and organs in vitro (in an artificial environment). With the famous aviator Charles A. Lindbergh, he developed a successful apparatus for supplying blood to whole organs to keep them alive outside the body.

Carrel retired from the Rockefeller Institute in 1939 and returned to France. He worked in the field of public health and promoted the French Foundation for the Study of Human Problems, with the purpose of finding practical solutions.

Among his best-known publ[illegible]ations are *Man, the Unknown* (19[illegible] *The Making of Civilized Man* (19[illegible] and, with Lindbergh, *The Culture* [illegible]*rgans* (1938).

Alexis Carrel

An ingenious glass instrument was developed by Alexis Carrel and the famous aviator Charles A. Lindbergh to supply blood to whole organs in order to keep them aliv[illegible]de the body. It was constructed with [illegible] of a glassblower at the Rockefeller I[illegible]

CARVER, GEORGE WASHINGTON
(1864?–1943)

Through the efforts of the U.S. botanist and agricultural chemist George Washington Carver, much of the worn-out farmland in the southern United States once again became productive. For years the soil-exhausting crops of cotton and tobacco had been depleting the ground of minerals; then Carver began his campaign to convince farmers that they should plant peanuts and sweet potatoes, crops that would replenish the soil. After succeeding in getting the farmers to plant these crops, Carver turned to the problem of what to do with the surplus of peanuts and sweet potatoes.

He began developing industrial uses for these plants. During his lifetime he invented no less than 300 synthetic products from the peanut and 118 from the sweet potato. These included coffee, flour, milk, cheese, soap, ink, dyes, wood stains, vinegar, molasses, and rubber. Another of his accomplishments was to make synthetic marble from wood shavings.

Carver was born to slave parents on a plantation near Diamond Grove, Missouri. As an infant he and his mother were stolen by raiders and carried off to Arkansas. Their original owner, Moss Carver, was able to find and buy back young George, but the mother was never found. After the passage of the Thirteenth Amendment to the U.S. Constitution in 1865, which freed the slaves, George was adopted by his former owner and given the surname Carver.

For part of his undergraduate work Carver attended Simpson College, Indianola, Iowa, the first Negro to enter that school. He received his bachelor's degree from Iowa State College, Ames, in 1894 and worked there as a botanist and teacher until 1896, when he was awarded a master's degree.

The U.S. botanist and agricultural chemist George Washington Carver devoted himself to agricultural experiments for the betterment of the South.

After graduating he accepted an appointment at Tuskegee Institute in Alabama and began his work in land reclamation. As director of the institute's Department of Agricultural Research, he first built up the poor soil surrounding the institute. He then went on to extend his efforts throughout the entire South. In 1935 he began working for the Bureau of Plant Industry, U.S. Department of Agriculture.

Carver never made a personal fortune from his remarkable list of synthetic plant products. In 1940 he donated his life's savings of $33,000 to establish a foundation that would carry on the work he had begun. In 1923 he was awarded the Spingarn Medal, and in 1939, the Roosevelt Medal. The area surrounding Carver's birthplace became a national monument in 1953.

CASSINI, GIOVANNI DOMENICO
(1625–1712)

The first director of the Paris Observatory was an Italian astronomer, Giovanni Domenico Cassini. He took up his post as director in 1667, and between 1671 and 1684 he discovered four of Saturn's satellites. In 1675 he also discovered the dark division in Saturn's ring.

Cassini was born at Perinaldo, near Nice, France. He received his education from the Jesuits at Genoa and later spent some years in papal service. In 1650 he was appointed professor of astronomy at the University of Bologna. There he wrote a treatise on the comet of 1652. In 1665 and 1666 he measured the periods of rotation of Jupiter and Mars and later prepared a table showing the motions of the moons of Jupiter.

He received permission from Pope Clement IX to work at the Paris Observatory, but with the stipulation that it would be a temporary arrangement. Cassini, however, never returned to live in Italy and in 1673 became a French citizen.

Some consider Cassini's most important work to be his determination of the parallax of Mars. He and Jean Richer made simultaneous observations of Mars at points 6,000 miles apart on the Earth. Cassini used these observations to calculate the distance of Mars. Using this calculation, he later figured the sun to be 87 million miles from the Earth—the most accurate estimate of the distance up to that time.

In 1655 the Italian astronomer Giovanni Domenico Cassini made a sundial for the Church of San Petronio in Bologna. It was used for the observation of solstices and equinoxes.

Giovanni Domenico was the first of four successive generations of the Cassini family to head the Paris Observatory. He was followed by his son Jacques Cassini (1677–1756), his grandson César François Cassini de Thury (1714–1784), and his great-grandson Jacques Dominique Cassini (1748–1845).

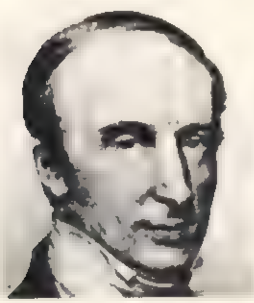
CAUCHY, BARON AUGUSTIN LOUIS
(1789–1857)

Among the most important contributions of the great French mathematician Augustin Louis Cauchy were his three major treatises clarifying the principles of calculus. He introduced rigor into calculus and clarified the principles with the aid of limits and continuity; he considered the integral to be the limit of a sum instead of the inverse of differentiation. He also invented the calculus of residues.

During his lifetime Cauchy wrote extensively, producing more than 700 papers on astronomy and physics, as well as on mathematics. His work on wave propagation won him the Institut de France Grand Prix in 1816. He developed an elaborate proof of the fundamental theorem of algebra, reorganized the theory of determinants, contributed substantially to the theory of numbers, originated the theory of stress and helped originate that of permutation groups, and developed the wave theory in optics. His theory of functions of a complex variable has found wide application in modern physics and aeronautics.

Cauchy was born in Paris and received

his early education from his father in the village of Arcueil, where the family lived during the Reign of Terror period of the French Revolution. The religious training instilled in him at that time contributed to his bigoted outlook, which in later life often made him disliked by his colleagues. As a young man Cauchy studied at the École Polytechnique and at the École des Ponts et Chaussées and worked for some time as a military engineer.



Augustin Cauchy

In 1813 he began to suffer from poor health. He was convinced by the mathematicians Joseph Louis Lagrange and Pierre Simon Laplace, friends of his father, to go into mathematics. By 1811 his mathematical ability had already been demonstrated in a paper on polyhedra, which came to the attention of the mathematician Adrien Marie Legendre.

From 1816 to 1830 Cauchy held three professorships in Paris, including one in mechanics at the École Polytechnique. He was fiercely loyal to the Bourbons—Charles X had made Cauchy a baron. After the Revolution of 1830 he refused to swear allegiance to Louis Philippe and went into exile. While in exile he held the chair of mathematical physics at the University of Turin in Italy.

Cauchy became a fellow of the Royal Society in 1832, and in 1838 he returned to Paris and resumed teaching at the École Polytechnique. From 1848 to 1852 he was professor of mathematical astronomy at the Sorbonne.

CAVALIERI, FRANCESCO BONAVENTURA (1598–1647)

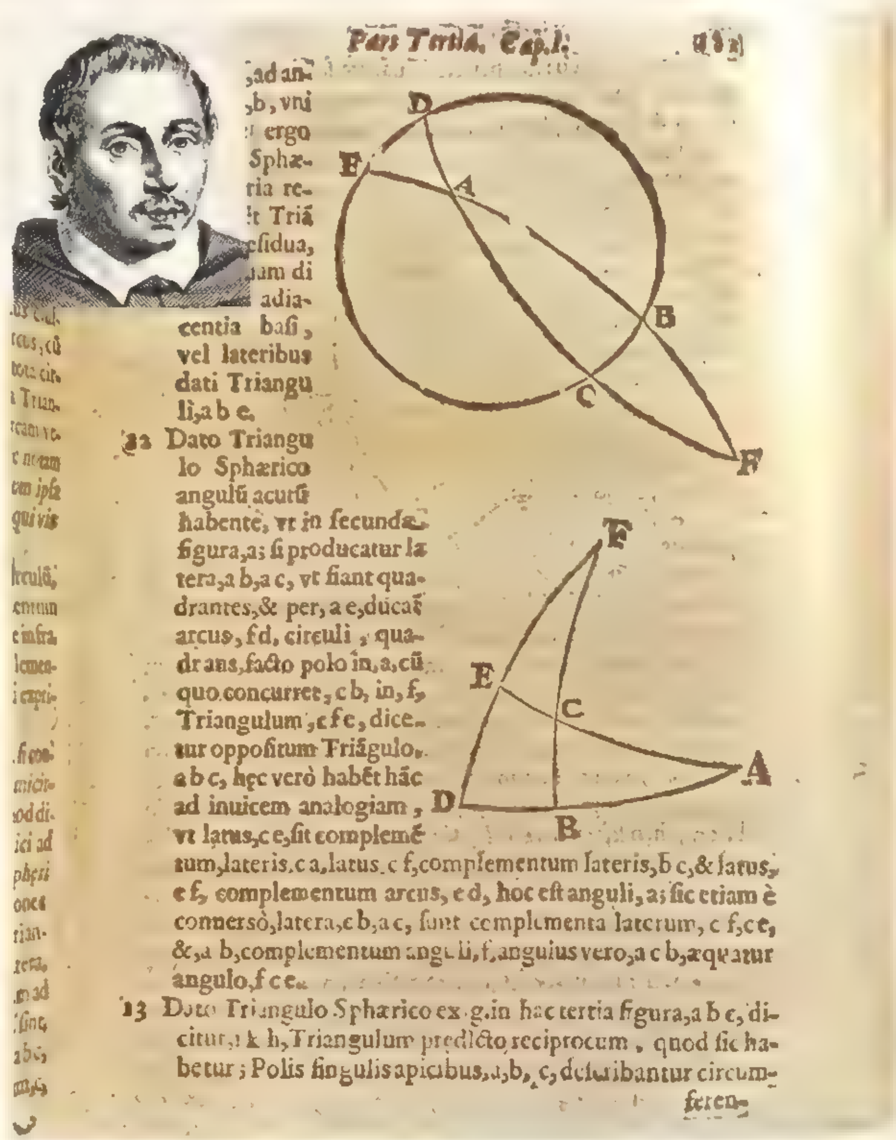
The Italian mathematician Bonaventura Cavalieri did much to aid the development of geometry during the Renaissance. His writings covered a number of subjects, including astrology, astronomy, conics, logarithms, optics, and trigonometry. He is most noted, however, for his method of indivisibles.

He stated his principle of indivisibles in his *Geometria indivisibilium continuorum nova quadam ratione promota*, published in 1635. The principle, as stated in this work, was unsatisfactory and was attacked by Paul Guldin. In response Cavalieri wrote *Exercitationes geometricae sex* in 1647, giving a more satisfactory form to his method of indivisibles. *Exercitationes geometricae sex* also contained the first rigorous proof of Guldin's theorem regarding the volume of a solid of revolution. Cavalieri later used his principle of indivisibles in a way similar to integral calculus, thereby solving many of the problems proposed by Johannes Kepler.

Cavalieri was born at Milan. His home was close to the monastery of the Jesuati, a minor monastic order that lasted for about 300 years, and he was so attracted by the tranquillity of monastic life that he joined the order at an early age. In 1619, when he was only twenty-one, he began to teach theology. After spending four years at the monastery in Milan, he was sent to the monastery of St. Jerome in Pisa. The enforced idleness of his life at Pisa was unsuited to his active intelli... but it was there that he was introduced to mathematics.

One of the inmates of the monastery was the famous mathematician Benedetto Castelli, a friend of Galileo. He befriended young Cavalieri and began to teach him a little mathematics. To his amazement Castelli found that in only two weeks Cavalieri had mastered everything that had been taught to him. Impressed by Cavalieri's obvious aptitude and ability for mathematics, Cas-

While professor of mathematics at the University of Bologna, Bonaventura Cavalieri produced many important works, such as *Directorium generale uranometricum* (1632), which helped spread the knowledge of trigonometry and logarithms throughout Italy. Among other things, it contains descriptive ... of triangles drawn on spherical sur...



Pars Tertia. Cap. I.

...ad an- ...b, vni ... ergo Sphæ- ...ria re- ...t Triã ...ſidua, ...iam di... adia- centia baſi, vel lateribus dati Triangu li, a b c.

12 Dato Triangu lo Sphærico angulũ acutũ habente, vt in ſecunda figura, a; ſi producatur la tera, a b, a c, vt fiant qua- drantes, & per, a e, ducatˢ arcus, f d, circuli quadrans, facto polo in, a, cũ quo concurrat, c b, in, f, Triangulum, c f e, dicetur oppoſitum Triãgulo, a b c, hęc verò habẽt hãc ad inuicem analogiam, vt latus, c e, ſit complemẽtum lateris, c a, latus, c f, complementum lateris, b c, & latus, e f, complementum arcus, e d, hoc eſt anguli, a; ſic etiam è converſò, latera, e b, a c, ſunt complementa laterum, c f, c e, &, a b, complementum anguli, f, angulus vero, a c b, æquatur angulo, f c e.

13 Dato Triangulo Sphærico ex g. in hac tertia figura, a b c, dicitur, a k h, Triangulum prędicto reciprocum, quod ſic habetur; Polis ſingulis apicibus, a, b, c, deſcribantur circum- feren-

telli introduced him to Galileo. The latter had great admiration for Cavalieri, and the two corresponded even after Cavalieri left Pisa.

Cavalieri's stay in Pisa was quite short and ended [illegible] a humiliating way. His fellow mon[illegible] who considered mathematics a pr[illegible] science, decided to distract him [illegible] his study by having him transferred [illegible] monastery of St. Benedict in P[illegible] Nevertheless, Cavalieri continued [illegible]athematical pursuits and while at [illegible] drafted his *Geometria indivisibi[illegible]*.

Meanwh[illegible] chair of mathematics at the Un[illegible] of Bologna had been vacant sinc[illegible]. Upon the strong recommendat[illegible] Galileo, Cavalieri was appointed [illegible]ssor of mathematics at Bologna in [illegible] a post he held until his death. Pop[illegible] VIII also made him prior for li[illegible] a monastery at Bologna so that he [illegible] fulfill his religious, as well as his [illegible] obligations.

CAVENDISH, [illegible]NRY (1731–1810)

One of [illegible] greatest, but most eccentric, scienti[illegible] all time was the English chemist an[illegible] sicist Henry Cavendish. His investi[illegible] produced major discoveries ab[illegible] the nature of electricity and about [illegible]perties of certain gases. What is ge[illegible] considered to be his greatest ac[illegible]ent, however, was the experimen[illegible]vised for estimating the density of [illegible] Earth.

Cavendis[illegible] born at Nice, France, while his [illegible] was on a trip for reasons of he[illegible] She never recovered her health and [illegible] when Cavendish was two years [illegible] He came from a noble family, his [illegible]ther being the daughter of the duke of Kent, and his father from the line that included the dukes of Devonshire. In later life Cavendish received an inheritance of about £1 million, making him one of the richest men of his time. He was not concerned with his wealth, however, and after his death most of the fortune went to relatives.

In 1749 he entered Cambridge and studied there until 1753, when he left without taking a degree. Being a very shy and retiring man, it appears that he felt unable to face the professors during the required examinations. For a time he studied physics in Paris and then moved to London.

The only interest in his life was scientific investigation. He lived in almost total seclusion, rarely spoke to anyone, and, having an intense fear of women, never married. Female servants in his household were instructed to stay out of his sight or face dismissal. He communicated with them by writing notes.

Cavendish avoided human contact as much as possible. So that he could come and go alone, he had a separate entrance built on his house. His library was located four miles from his home because he did not wish to be disturbed by those who wanted to use the library.

In 1760 he was made a fellow of the Royal Society. He attended the meetings regularly, and apparently his only social contact was with the members of the society. In 1808 he was chosen one of the few foreign associates of the Institut de France.

Cavendish was motivated in his work only by his own curiosity. He was not interested in either personal fame or fortune and was not concerned about whether or not his findings were published. Only a few of his major investigations were published during his lifetime, and for this reason his findings regarding the nature of electricity went unknown for a century.

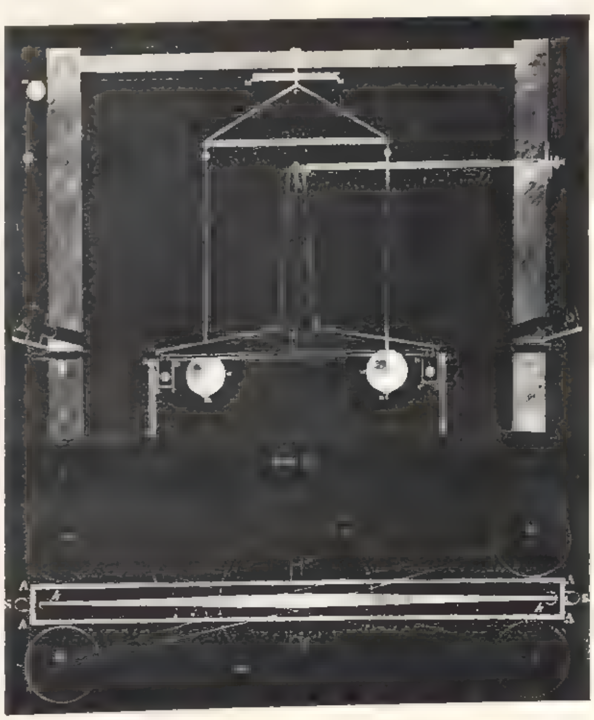
Cavendish experimented with electricity in the 1770s. He studied the capacity of condensers, using the "inch of electricity" as the unit for his measurements of potential. This potential he called the degree of electrification. He discovered that the electric charge is confined to the conducting surface and investigated the ability of different substances to conduct electricity. For all his brilliance, Cavendish had little ability at inventing scientific instruments; he measured the strength of a current by shocking himself and then estimating the degree of the pain. Nevertheless, his work in electricity anticipated that of Charles Augustin de Coulomb, Michael Faraday, and Georg Simon Ohm.

In 1766 he published a paper describing what he called "inflammable air," which later came to be known as hydrogen. Cavendish was the first to systematically study the properties of hydrogen and of carbon dioxide, which he called "fixed air." He also determined the specific gravity of both these gases. In the early 1780s he discovered, by burning hydrogen, that water results from the union of hydrogen and oxygen.

In 1785 he discovered the composition of nitric acid. By passing electric sparks through air, he forced the nitrogen and the oxygen to combine. He then dissolved the resulting oxide in water and thereby produced nitric acid.

During this experiment he inadvertently discovered argon but was never aware of his discovery. Noticing that a small bubble of gas would not dissolve in the water, he assumed that air contains a small amount of an inert gas. More than a century later this gas was identified as argon.

In 1798 he began his famous experiment to determine the density of the Earth. Even though Newton had worked out the law of gravitation, the gravitational constant had remained an un-



Using a type of balance that he had constructed, which consisted of a rod and light and heavy lead balls, Henry Cavendish conducted experiments that helped him solve Newton's equation and calculate the gravitational constant and the Earth's mass.

Henry Cavendish

known. To determine the mass of the Earth, it was necessary to know the gravitational constant—which it was assumed would be the same for all bodies—and so Cavendish set about to discover it.

In his experiment (often called the Cavendish experiment, though it was first suggested by his contemporary John Michell), he hung a rod horizontally from a wire attached to the center of the rod. At each end of the rod, he attached light lead balls and then determined the amount of force that would twist the wire attached to the free-swinging rod. After carefully measuring this reaction, he brought two larger balls toward the small balls at each end of the rod. The gravitational force between the large and small balls caused the wire to twist, and from the extent of the twist Cavendish was able to figure the gravitational force. He used the information from this experiment to solve Newton's equation, then went on to calculate the gravitational constant, and finally determined the mass and the density of the Earth.

During his career Cavendish made a number of other discoveries and conducted many important studies. He was the first person to measure the weight of gases to determine their density. In 1783 he demonstrated that the composition of the atmosphere is constant. While analyzing ordinary pump water, he discovered calcium bicarbonate. Also, he experimented with arsenic, investigated the freezing point of mercury, and studied heat, which he regarded as being produced by the internal motion of tiny particles. The Cavendish Physical Laboratory at Cambridge was named in his honor.

CAYLEY, ARTHUR (1821–1895)

One of the most prolific mathematicians of all time was Arthur Cayley, who wrote more than 600 papers on a wide variety of mathematical topics. He was able to unite Euclidean and non-Euclidean geometry under a common theory. Probably his major contribution to mathematics was a series of ten papers on algebraic forms, developing his theory of invariants. Cayley was strongest in the area of pure mathematics and not so strong in applied mathematics.

A close colleague for much of his life was James John Sylvester, whom he met at school. Cayley and Sylvester worked together in developing the invariant theory, and it is difficult to separate the efforts of one from the other.

Cayley was born in Richmond, Surrey, England. At King's College School in London he showed his mathematical aptitude very clearly. He was further educated at King's College, Cambridge, but his career there came to a halt when he refused to take religious orders. In 1846 he began studying law at Lincoln's Inn and was admitted to the bar in 1849. He practiced law for fourteen years, studying mathematics and writing about it in his spare time.

He was able to return to Cambridge in 1863 to assume the newly created Sadlerian Professorship of Pure Mathematics. He held that post until his death. In 1881–1882 he took time off to lecture in the United States, at Johns Hopkins University, Baltimore, Maryland, where his friend Sylvester was teaching.

The private life of Arthur Cayley was lively and interesting; although he was very erudite, he was no ivory tower scholar. Cayley was an avid fiction reader, and in his leisure time he liked to paint in water-colors. Mountaineering was one of his recreational pursuits. He married at the age of forty-two.

CAYLEY, SIR GEORGE (1773–1857)

The founder of aerodynamics was the British scientist Sir George Cayley. He invented the airplane, but he was unable to make one that would fly. Orville and Wilbur Wright, who flew the first airplane in 1903, paid tribute to Cayley's pioneering efforts.

For years, men who contemplated building a flying machine tried to imitate a bird in their designs by always including flapping wings. Cayley dropped that idea and developed the fixed wing. By 1799 Cayley had established the basic shape and configuration of an airplane, with the essential parts being fixed wings, fuselage, vertical tail unit, and airscrew.

The basic principle of aerodynamics for any craft heavier than air is that air resistance must be made to work in favor of the craft and that a suitable means of propulsion must be provided. Cayley understood and articulated this principle, but he was unable to devise an engine with enough power to support the craft.

In 1804 Cayley sent up his first successful model glider. The high point of his career, however, came in 1853, when he sent up a glider carrying a passenger; this was the first man-carrying flight in history.

Cayley was born in Scarborough, Yorkshire, England. As a child he went to school in York; later he studied under private tutors. He had independent financial means and thus was able to devote much of his life to writing and research on aeronautics. He had general interests as an inventor and is also credited with inventing the Caterpillar tracks and railroad signals. He was a founder of the Royal Polytechnic Institute of London and a founding member of the British Association for the Advancement of Science.

In 1804 the English scientist George Cayley flew the first of his successful model gliders. Despite its small wing surface, it was able to lift off the ground because Cayley had made the fundamental discovery that the wing contour, instead of being flat, must be concave like that of a bird's wing to increase the lift of the wing surface. Theoretical considerations and practical tests enabled Cayley to define almost completely the form and structural elements of the modern airplane. He understood also the reasons for the instability of an aircraft and submitted suggestions that introduced the stabilizing rudder.

Sir George Cayley

CERENKOV. See Cherenkov, Pavel Alexseevich.

CHADWICK, SIR JAMES (1891–   )

The neutron, an atomic particle without electric charge but with a mass roughly equal to that of the proton, was discovered by Sir James Chadwick in 1932. Other scientists had postulated the existence of such a particle, but Chadwick was the first to provide an acceptable proof that neutrons exist. The concept of the neutron is very important in nuclear physics, and for his discovery Chadwick received the 1935 Nobel Prize in physics.

Chadwick was born in Manchester, England. He received his degree in physics from Manchester University in 1911. He then went to Germany to study at the Charlottenburg Institute; during World War I he was detained as a civilian prisoner of war. After the war he went to Cambridge, and in 1922 he was elected a fellow of Gonville and Caius College there. Then he was appointed assistant director of the Cavendish Laboratory, where he worked under the famed British physicist Ernest Rutherford.

In the 1920s, two atomic particles were known: the electron and the proton. They formed the nucleus of the atom, and Rutherford and Chadwick were convinced that the nucleus also contained an uncharged particle. Irène and Frédéric Joliot-Curie had bombarded beryllium with alpha particles and then had studied the resulting radiation—which knocked the protons from paraffin wax. Chadwick repeated their experiments and showed that the protons were displaced by the neutral particles, or neutrons, in the beryllium radiation.

In 1935 Chadwick became professor of physics at Liverpool University, where he inaugurated the study of nuclear physics. During World War II he was head of the British group participating in the Manhattan Project to develop the atom bomb; for this work U.S. President Harry S. Truman awarded him the Medal for Merit in 1946. Returning to Cambridge in 1948, Chadwick became master of Gonville and Caius College.

He was elected a fellow of the Royal Society in 1927 and received its Hughes Medal in 1932. His other awards include the Franklin Medal of the Franklin Institute of the State of Pennsylvania (1951). He was knighted in 1945.

Sir James Chadwick

The existence of neutrons was proved by the British physicist James Chadwick in 1932 when, repeating the experiments of Irène and Frédéric Joliot-Curie, he showed that in the bombardment of beryllium with alpha particles, the protons were displaced by a particle of a mass approximately equal to that of the protons but without electric charge—that is, the neutrons. This discovery of a third stable particle in the atom was of utmost importance for atomic disintegration, since neutrons, being electrically unchanged, could penetrate undeflected into the atomic nucleus.

CHAIN, ERNST BORIS (1906–   )

For his prominent role in making penicillin available and effective for treating bacterial infection in humans, Ernst Boris Chain shared in the 1945 Nobel Prize in medicine or physiology. The German-British biochemist was honored along with his collaborator, Howard Walter Florey, and the discoverer of penicillin, Alexander Fleming. (*See* Sir Alexander Fleming; Sir Howard Walter Florey.)

Working with Florey, Chain helped in the discovery of means to extract, concentrate, and purify penicillin. Their triumph came in 1939, in time to save many lives during World War II.

Ernst Chain

Chain, the son of a chemist, was born in Berlin, Germany. Visits to his father's laboratory excited the boy's interest in chemistry, and he went on to study physiology and chemistry at Berlin's Friedrich-Wilhelm University. After graduation in 1930 he did research work in the chemical department of the Institute of Pathology at Charité Hospital in Berlin. In 1933 he went to England to work under the direction of the English biochemist Sir Frederick Gowland Hopkins at Cambridge.

Two years later Florey invited Chain to Oxford University, where he became a demonstrator and lecturer in chemical pathology. The achievements of Chain and Florey in penicillin research grew from a systematic investigation of antibacterial substances produced by microorganisms.

Early tests of penicillin showed 90 percent recovery rates in mice that had been infected with gas gangrene bacteria. All the untreated (control) mice died. Penicillin continues to be the most widely used antibiotic.

Among Chain's other contributions to biochemistry was the discovery of penicillinase, an enzyme that causes some bacteria to resist penicillin. He was instrumental as well in demonstrating the chemical structure of crystalline penicillin.

Chain went to Rome, Italy, in 1948 as scientific director of the International Research Center for Chemical Microbiology. In 1961 he returned to England to become professor of biochemistry at the Imperial College, University of London, where a new laboratory was built for him. Chain was elected a commander of the Legion of Honor and a fellow of the Royal Society, and in 1954 he received the Paul Ehrlich Centenary Prize.

CHAMBERLAIN, OWEN (1920–)

In 1955 the U.S. physicist Owen Chamberlain, working with his colleague Emilio Segrè at the University of California, confirmed the existence of the antiproton. The antiproton is a negatively charged particle with a mass, or weight, equal to that of a proton. For their proof Chamberlain and Segrè received the 1959 Nobel Prize in physics. (*See* Emilio Segrè.)

Owen Chamberlain

For approximately twenty years, scientists had speculated on the existence of the antiproton. A high-energy source was needed to produce the antiproton, because of the great mass of the proton and, by inference, the antiproton. Chamberlain and Segrè were able to utilize the powerful bevatron at the University of California; they bombarded copper atoms with high-energy protons. The next step was to identify and isolate the antiprotons among the new particles formed. They had produced one antiproton for every 30,000 particles. As they were separating out the antiprotons on a magnetic field, they measured the velocity of the particles to determine the mass of the particles and were thus able to demonstrate that the antiproton had the same mass as the proton.

Chamberlain was born in San Francisco, California. He was graduated from Dartmouth College, Hanover, New Hampshire, in 1941. From 1942 to 1946 he worked as a physicist on the Manhattan Project to develop the atomic bomb. Next he worked at the Argonne National Laboratory near Chicago, Illinois, while he did graduate work at the University of Chicago. The brilliant physicist Enrico Fermi was one of his teachers at Chicago; Chamberlain received his doctorate from there in 1949. He joined the faculty of the University of California at Berkeley in 1948 and began working with Segrè on the antiproton in 1955. Chamberlain was appointed professor of physics at Berkeley in 1958. He was elected to the National Academy of Sciences in 1960.

CHELPIN. See Euler-Chelpin, Hans Karl August Simon von.

CHERENKOV, PAVEL ALEKSEEVICH (1904–)

For his discoveries concerning electron radiation the Soviet physicist Pavel Alekseevich Cherenkov received the 1958 Nobel Prize in physics. His co-winners were Ilya Mikhailovich Frank and Igor Evgenyevich Tamm. (*See* Ilya Mikhailovich Frank; Igor Evgenyevich Tamm.)

High-energy particles were sent through a medium faster than the speed of light in that medium. In their wake the particles left a trail of light waves that Cherenkov was able to detect. The process is called the Cherenkov effect, and the waves are called Cherenkov radiation. Cherenkov made his observations in 1934, and Frank and Tamm provided detailed explanations in 1937.

A Cherenkov counter uses Cherenkov radiation to select high-energy particles and to allow others to pass on. This counter has been very useful to other physicists in their particle studies.

Cherenkov was born in Voronezh Guberniya, Russia, and graduated from Voronezh University in 1928. After 1930 he worked at the Lebedev Institute of Physics of the Academy of Sciences of the U.S.S.R., where he worked with Frank and Tamm, as well as with S. I. Vavilov. Cherenkov also served as professor at the Moscow Physical Engineering Institute. For their discoveries Cherenkov, Frank, and Tamm received the Stalin Prize in 1946.

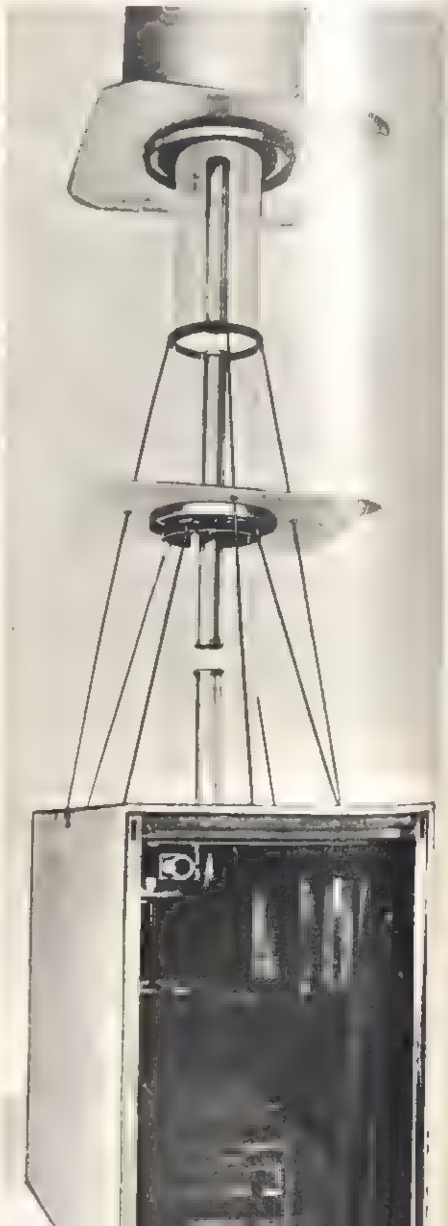
COCKCROFT, SIR JOHN DOUGLAS (1897–1967)

For smashing the atom—breaking down its nucleus—by means of artificially generated protons, the British physicist Sir John Douglas Cockcroft and his coworker Ernest Thomas Sinton Walton received the 1951 Nobel Prize in physics. (*See* Ernest Thomas Sinton Walton.)

In the 1920s Cockcroft and Walton

Sir John Cockcroft

For the splitting of atomic nuclei the British physicist John Douglas Cockcroft and his colleague Ernst Walton used an instrument of their own design. They succeeded in disintegrating the nuclei of lithium and other light elements by bombarding them with protons that had been produced by passing an extremely high electric current through a tube filled with hydrogen. This achievement was later of importance in developing the hydrogen bomb.



worked at the Cavendish Laboratory with the renowned Sir Ernest Rutherford. In Rutherford's laboratory natural alpha particles were used to smash the atom, but the search continued for new high-energy levels that would do the job artificially. In 19[illegible] Cockcroft and Walton pushed prot[illegible] very high energy levels and then us[illegible] to bombard lithium atoms. This [illegible]ed a nuclear reaction of lithium w[illegible]drogen. As it happened, this nuclear [illegible]ion was very important later in the [illegible]ment of the hydrogen bomb.

Cockcroft [illegible] born in Todmorden, Yorkshire, E[illegible]. He studied mathematics at M[illegible]ster University for a year but th[illegible]nt away to fight in World War [illegible]hen he returned, he studied elect[illegible]gineering at the College of Tec[illegible], Manchester. He received a do[illegible]in mathematics from Cambridge [illegible]sity in 1928.

He was a [illegible]w of St. John's College, Camb[illegible] from 1928 to 1946. While engag[illegible] defense research, he also held the [illegible] of professor of natural philosophy a[illegible]mbridge from 1939 to 1946. He se[illegible] chief of Britain's air defense rese[illegible]rom 1941 to 1944. The National R[illegible] Council of Canada claimed his [illegible]s from 1944 to 1946, when he d[illegible] the council's atomic energy divis[illegible] 1946 he was appointed head of Br[illegible] first atomic energy laboratory, [illegible]d at Harwell. The United King[illegible]tomic Energy Authority was set u[illegible]954 to coordinate and oversee ato[illegible]search efforts; Cockcroft was [illegible]member for scientific research. I[illegible]he was appointed master of the ne[illegible]urchill College at Cambridge, and [illegible] 1961 to 1965 he served as chancellor [illegible] the Australian National University.

In his lifetime Cockcroft was greatly honored on many occasions. He received more than twenty honorary degrees from various universities. He was elected a fellow of the Royal Society in 1936 and was awarded its Hughes Medal in 1938 and its Royal Medal in 1954. Cockcroft was knighted in 1948 and made Knight Commander of the Bath (KCB) in 1953. From the United States came the Atoms for Peace Award in 1961.

COHN, FERDINAND JULIUS (1828–1898)

The German botanist Ferdinand Julius Cohn made the first systematic attempt to classify bacteria into genera and species. The basic elements of his classification remain in current usage. Cohn published a treatise on bacteria that, in effect, founded the science of bacteriology.

Cohn was born in Breslau, Silesia (now Wroclaw, Poland), and studied at the universities of Breslau and Berlin. He became an associate professor of botany at Breslau in 1859 and a full professor in 1871. In his doctoral thesis Cohn urged that the state establish institutes for the study of plant physiology. Through his offices the Institute of Plant Physiology was opened at the University of Breslau in 1872, with Cohn as its director.

In 1870 Cohn founded his journal of plant biology. In its pages he published the milestone discovery by Robert Koch, then unknown, that *Bacillus anthracis* causes anthrax, showing for the first time that a specific disease is caused by a specific bacterium.

Early in his career Cohn was interested in the microscopic study of algae and fungi. He showed that the protoplasm of plant and animal cells are essentially the same and that there is only one physical basis for life. He discovered also the formation and germination of spores and their resistance to high temperatures. Among his many honors was his election as a foreign member of the Royal Society of London.

COLUMBUS, CHRISTOPHER (1451–1506)

On October 12, 1492, the explorer Christopher Columbus first set foot on America. Northmen had discovered America about 500 years before, but their discovery was virtually forgotten. Columbus opened America to settlement and colonization by Europeans; on his fateful voyage he was actually searching for a western sea route from Europe to Asia, and to the day he died he mistakenly believed that he had found Asia.

He was born Cristoforo Colombo in Genoa, Italy, the son of a weaver. He had little or no formal education and went to sea at an early age. In 1476 he sailed as a seaman on board a ship bound for Lisbon, Portugal; the ship went down, but Columbus managed to make his way to shore. He decided to stay in Portugal, which at that time was the western end of the known world—a natural jumping-off point for explorers.

After 1476 he sailed the South Atlantic and became familiar with it. Also, he acquired some skills as a chart maker. In 1481 he entered the service of King John II of Portugal and sailed to Africa.

When he began to look for a patron for his explorations, Columbus turned first to King John but was refused. He then went to Spain to present his plan to the king and queen, Ferdinand and Isabella, who finally agreed to back him.

Columbus sailed from Palos, Spain, on August 3, 1492, commanding the *Santa Maria;* the other two ships in his party were the *Niña* and the *Pinta.* They stopped at the Canary Islands for repairs and then got under way from there. Columbus had an inaccurate system for recording mileage, and he thought he was going much farther than he actually was. The crew became restive in the uncharted waters, and there was some danger of mutiny. Finally, on October 12, at 2:00 A.M. a seaman sighted land. They sailed into the Bahama Islands and named the first land sighted San Salvador

Christopher Columbus

(now Watling Island). Columbus and a party of his men disembarked and made contact with the natives, whom he called Indians because he believed he was in India. Then they sailed on to several other small islands, eventually reaching the north coast of Cuba, which he called Juana. Columbus decided to land at a place he called Hispaniola; he built a settlement called Villa de la Navidad and left thirty-eight men to live there.

The *Santa Maria* was wrecked and had to be abandoned. Columbus returned to Spain on the *Niña,* reaching Palos on March 15, 1493. He was given a triumphal welcome and great wealth.

He made three more trips to the New World. On the second voyage, 1493–1496, he took seventeen ships and brought more colonists. There were some rumors that Columbus was not a good governor, and the colonists he had brought wanted to search for gold rather than farm. On this trip he discovered Guadeloupe, Puerto Rico, Jamaica, and part of the Virgin Islands. During his third voyage, 1498–1500, he discovered Trinidad. While he was away, Ferdinand and Isabella became convinced that he was a bad administrator and a tyrant. They sent in a new governor and had Columbus brought back in chains. When he was returned, he was able to convince them that the charges were false. He was freed and allowed to make a fourth voyage, 1502–1504. He returned to Spain in ill health and died there.

COMPTON, ARTHUR HOLLY (1892–1962)

Using matter to scatter x-rays, the U.S. physicist Arthur Holly Compton found that the resultant radiation has a longer wavelength, and thus less energy, than the original radiation. This is known as the Compton effect, discovered in 1923. Compton showed that the angle of scattering affects the change in wavelength. For his discovery he shared the 1927 Nobel Prize in physics with Charles T. R. Wilson, the developer of the cloud chamber. (*See* Charles Thomson Rees Wilson.)

The wave properties of light seemed well established before Compton's discovery. Compton showed that radiation has a dual nature, encompassing waves and particles. In the Compton effect, electrons collide with light photons, and energy bounces into the electrons from the photons.

In the 1930s Compton concentrated on studying cosmic rays. In 1933 he organized a worldwide survey of cosmic rays, and the results confirmed the idea that the intensity of the rays varies with latitude and, among other factors, the time of the day and the season.

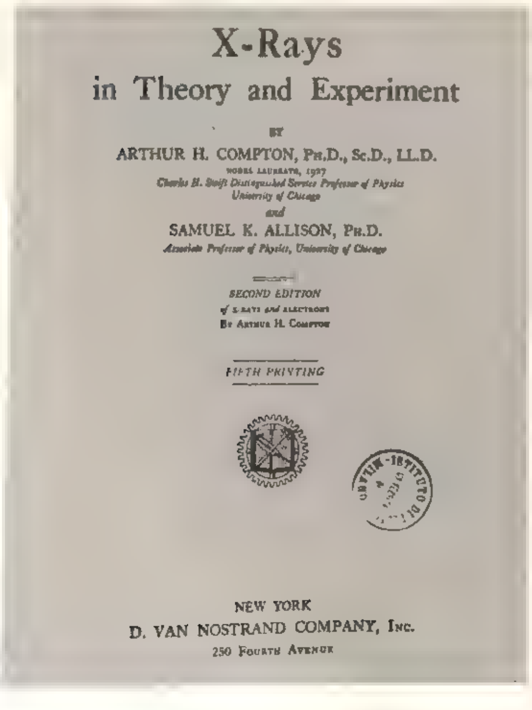
Compton was born in Wooster, Ohio, the son of a Presbyterian minister. He graduated from Wooster College in 1913 and received a doctorate in physics at Princeton University in 1916. After teaching physics at the University of Minnesota for one year, he was engaged in industrial research for two years in Pittsburgh, Pennsylvania. In 1919 he went to England to study at Cambridge University for a year under the renowned Ernest Rutherford. In 1920 Compton became professor and head of the physics department at Washington University, St. Louis, Missouri. In 1923 he became professor of physics at the University of Chicago and eventually rose there to chairman of the department and dean of the Division of Physical Sciences.

During World War II he became director of the so-called Metallurgical Project at the University of Chicago, which developed the first atomic chain reaction. From 1942 to 1945 he was in charge of plutonium production for the atomic bomb.

After the war Compton returned to Washington University as chancellor, serving in that post from 1945 to 1953. He was professor of natural philosophy at the university from 1953 to 1961.

Arthur Holly Compton

X-Rays in Theory and Experiment (1935) was one of Arthur Holly Compton's most important works.



X-Rays
in Theory and Experiment

BY

ARTHUR H. COMPTON, PH.D., SC.D., LL.D.

NOBEL LAUREATE, 1927

Charles H. Swift Distinguished Service Professor of Physics

University of Chicago

and

SAMUEL K. ALLISON, PH.D.

Associate Professor of Physics, University of Chicago

SECOND EDITION

of X-RAYS *and* ELECTRONS

BY ARTHUR H. COMPTON

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COOK, JAMES (1728–1779)

The English explorer Captain James Cook "did more to clarify the geographical problems of the Southern Hemisphere than had been done by all his predecessors," according to the *Encyclopædia Britannica*. Captain Cook surveyed more coastline than any other explorer, and he virtually remade the map of the Pacific. His talents in astronomy were considerable, and he is said to be the first genuinely scientific explorer.

Cook was born in Marton, Yorkshire, England, the son of a farm laborer. He was apprenticed as a boy to a shop owner and later to a shipowner. In 1755 he joined the Royal Navy. By 1759 he qualified as master of the *Mercury*, which made expeditions on the St. Lawrence River. Next he served as marine surveyor of the coasts of Newfoundland and Labrador, writing a detailed account of a solar eclipse off Newfoundland.

Three great voyages marked Captain Cook's career. The first was made in the *Endeavour* from 1768 to 1771. He set out to observe the transit of Venus in the South Pacific. He spent about six months circumnavigating the coast of New Zealand and made detailed maps from his observations. In 1770 he became the first European to reach the eastern coast of Australia, which he named New South Wales. On this voyage he also discovered the Admiralty and Society islands and explored New Guinea.

On his second great voyage, 1772–1775, he led two ships, the *Resolution* and the *Adventure*. Cook wanted to test the theory that there were other continents in the Pacific southeast of Australia. He became the first European to cross the Antarctic Circle. Although he never reached the continent of Antarctica, he was able to show that there was no other continent but that one south of Australia. He fully explored the southern Pacific, mapping known islands and discovering new ones. His journey completed man's

In his search for the Northwest Passage, Captain James Cook was turned back by ice at

the Bering Strait and returned to Hawaii, where he was killed in a skirmish with the natives.

exploration of the oceans, except for the polar regions.

This voyage was notable for medical and humanitarian reasons. Captain Cook was able to prevent an outbreak of scurvy on board his ship—the fatal disease that had haunted British sailors. Upon his return to England, Cook received the Copley Medal of the Royal Society.

His third voyage, begun in 1776, was made with the *Resolution* and the *Discovery*. First he sailed to the Hawaiian Islands, which he called the Sandwich Islands. Since the real purpose of the journey was to find the Northwest Passage, he next sailed north; but heavy ice blocked his passage through the Bering Strait and forced him to turn back. Upon his return to Hawaii, he was killed in a fight with the natives.

COPERNICUS, NICOLAUS (1473–1543)

During the Renaissance the sciences made progress, but there were no real innovations. In order to refute the erroneous Ptolemaic system of the Earth as center of the universe, new ideas and a genius were needed; but this genius had to be a patient person, whose only concern was the search for truth, without any desire for its overhasty affirmation. Nicolaus Copernicus proved to be the man.

There is still a village in Silesia called Kopernik, from which Nicolaus' family appears to have originated. He was born, however, at Torun, on the Vistula River, to a merchant, Mikolaj Kopernik, and a noblewoman, Barbara Waczenrode.

He was the youngest of four children, and his father died when he was ten. He was cared for by his maternal uncle Lucas, who later became bishop of Warmia, an important diocese, and who in this capacity was a prince to the empire for twenty-three years. Nicolaus was first sent to the capitulary school at Wloclawek and at the age of eighteen to Cracow University to study letters and mathematics for four years. It was his uncle who conferred minor orders on him when he had finished his studies.

He was extremely gifted artistically, as can be seen from several lifelike self-portraits; and, following the trend of the time, he was also interested in medicine and astronomy. Attracted by the fame of the scholars of a country that boasted so many great men in the sciences and the arts, Copernicus went to Italy for about a decade to pursue these studies at the universities of Bologna, Rome, Padua, and Ferrara.

When he returned home for a visit, his uncle obtained for him a canonry of Frauenburg Cathedral (the seat of the diocese). More attracted by his studies, however, than by his ecclesiastical duties, he occupied it only during his next brief visit from Italy.

By 1505, however, he had returned permanently to Poland, where he acted as secretary to his uncle until the latter's death. While the see was vacant (1516–1521), Copernicus was responsible for the administration of the diocese, a task that he performed with skill and energy. He even had to fight against the Teutonic Knights, who had formerly been supporters of the church but had become difficult neighbors on account of their arrogance and violence.

The chapter—in other words, the college of the cathedral canons—appointed him as its spokesman to deal with the country's grave economic situation. There was a threat of inflation, resulting from inefficient administration and the various cities' independent coining of their own currency (medieval coins from Germany and the neighboring states constitute half the numismatic gold collections of the world). He proposed simple, practical, and judicious measures, but these were not adopted as a result of popular ignorance and the administrators' cupidity.

This long period of administration was the only time when Copernicus took part in public life. In 1514 he refused an invitation to Rome to expound his views on the reform of the calendar at the Lateran Ecumenical Council because he considered that existing knowledge of the movements of the sun and moon was imprecise and did not feel inclined to talk on a subject that had not been sufficiently studied. He was glad to return to a life divided between his easy duties as a canon, the medical treatment that he dispensed efficiently and disinterestedly, and his studies in astronomy.

The Ptolemaic system satisfied superficial intuition; and for this reason, combined with the fact that it was in accordance with the primitive astronomical conception of the Holy Scriptures, it remained unchallenged for many years. Any attempt at explaining the movement of the planets and fixed stars according to the Ptolemaic hypothesis was fraught with difficulties. In order to destroy it a simpler hypothesis had to be advanced. But this was no easy undertaking, for it was impossible to collect such concrete arguments as measurements in order definitively to refute the Ptolemaic hypothesis (this was accomplished only much later, through Galileo's discoveries and Kepler's measurements). How was it possible to present a hypothesis that was based on brilliant intuition rather than on valid arguments? Moreover, the state of astronomical research was such that it would be a long time before this hypothesis could be supported by experimental observations. And how could the inevitable opposition of the church be overcome? Copernicus had already published a pamphlet, probably in the year 1507, entitled *De hypothesibus motuum coelestium a se constitutis commentariolus* (a brief treatise by Nicolaus Copernicus on the hypothesis advanced by him concerning the movements of the heavens), in which he no doubt used the word *hypothesis* to safeguard himself against the ecclesiastical censure that the work would inevitably provoke.

It is not known whether the heliocentric idea was suggested to him by discussions with D. M. Novara or with other contemporaries. Copernicus cites only the ancient writers who had been the first supporters of this hypothesis to confirm his growing convictions on the subject.

There is no indication as to the date of the work that contains his hypothesis on the system of the universe, *De revolutionibus orbium coelestium.* It was perhaps written as early as 1503–1504 but remained unpublished until 1543, the year of his death. Copernicus had preferred to continue his work in obscurity, perfecting it and strengthening his convictions with observations of the sky from the terrace of the tower where he lived, which had once been a fortress.

He freely revealed his ideas to his few followers. One of them was Georg Joachim Rhäticus, who had left his chair at Wittenberg University to be close to his teacher, with whose consent he published a treatise, *Narratio prima*, containing a brief summary of the Copernican hypothesis. This hypothesis gradually and unobtrusively spread through Europe, and Copernicus was urged to present it in a complete published form. He finally decided to do so in 1543; and allegedly the first copy, brought from Nürnberg, where it had been published anonymously, was shown to him on his deathbed.

Osiander, who published the work, added a preface in which he declared that the author did not believe in his hypothesis—in fact, considered it unfounded—but treated it as a useful geometric exercise. This perhaps saved the work from the anathema of heresy but also prevented it from being taken into serious consideration for a long time. It caused no stir or scandal but was met with widespread indifference and the enthusiasm of only a few advocates, such as Cardinal Schomberg and Bishop Tydeman Gize, who worked to gain Pope Paul III's approval for it, Giordano Bruno, Galileo, Kepler, and the courageous Father Foscarini. Among the Protestants, on the other hand, it provoked immediate and violent opposition; both Luther and Melanchthon were against it. The Catholic church put it on the Index only in 1615, when it formally condemned the theory. Many documents on the life of Copernicus were destroyed in the course of wars; but the manuscript of the *De revolutionibus* was saved, and it remains the richest source of information about the character of the man.

Nicolaus Copernicus

In 1501 Nicolaus Copernicus entered the University of Padua, where, enrolled in the register of Polish students, he studied law and medicine. He had already studied letters and mathematics at Cracow; but because he was interested in many other subjects—particularly astronomy, medicine, and art—he went to Italy, which was famous for its eminent scholars.

CORI, CARL FERDINAND (1896–) and GERTY THERESA RADNITZ (1896–1957)

The 1947 Nobel Prize in medicine or physiology was awarded to a husband-and-wife team of biochemists, Carl Ferdinand and Gerty Theresa Radnitz Cori. They shared the prize with Bernardo A. Houssay of Argentina. (*See* Bernardo Alberto Houssay.)

In the 1930s the Coris began their Nobel Prize-winning studies of the metabolism of glycogen, a carbohydrate stored in muscle. They provided detailed chemical studies of how the enzymes react in the conversion of glycogen to lactic acid. One of their greatest achievements was the isolation of a previously unknown compound from the muscle tissue. This compound is usually called the Cori ester, but its full scientific name is glucose-1-phosphate. The Coris' work was important to both biochemistry and medicine.

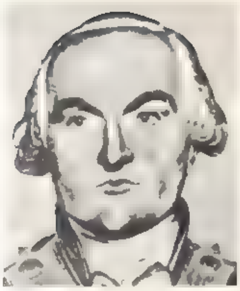
Carl and Gerty were both born in Prague, Austria-Hungary (now Czechoslovakia). They met as medical students at the German University of Prague. Carl's education was interrupted during World War I, when he served in the Austrian army, but in 1920 he and Gerty received their medical degrees.

In 1922 the Coris began a new life by moving to the United States. They became citizens in 1928. For nine years Carl was a biochemist at the Institute for the Study of Malignant Disease in Buffalo, New York. In 1931 Carl and Gerty joined the faculty of the Washington University Medical School, St. Louis, Missouri. Carl became chairman of the biochemistry department there in 1947.

COULOMB, CHARLES AUGUSTIN DE (1736–1806)

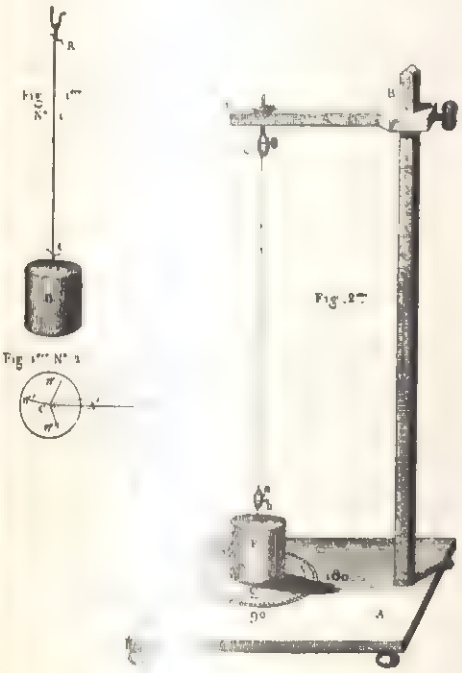
One of the great eighteenth-century physicists was Charles Augustin de Coulomb. He published his notable papers on electric charges between 1785 and 1789. One of his papers shows that an electric charge is confined to the surface of a conductor.

In another paper he set forth what came to be known as Coulomb's law. He had invented a torsion balance in 1777, and he described how he used it in electrical experiments. He could measure the attraction or repulsion of two electrically charged spheres. Coulomb's law states that in electric attractions or repulsions the force is proportional to the product of the two charges and inversely proportional to the square of the distance between the two charges. An electrical unit was named the coulomb in his honor.



Charles de Coulomb

With his torsion balance Charles de Coulomb tested the torsional elasticity of silk fibers.



He also did research on magnetism, establishing the equation that expresses the motion of a magnet in a magnetic field. After he made his discoveries about electric charges, he also applied his law of attraction to magnetism.

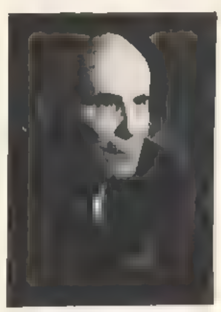
Coulomb was born in Angoulême, France. Little is known about his early life. He spent nine years in the West Indies as a military engineer, and his health was weakened there. In 1784 he was placed in charge of the water system of France. In 1786 he became head of planning. At the beginning of the French Revolution of 1789, he was removed from his post on the weights and measures commission. Under an edict expelling nobles from Paris, he left the city and resettled in the provincial town of Blois. While in the country, he concentrated on research and writing. He was able to return to Paris in 1795, and later he was named an inspector of public instruction.

COURNAND, ANDRÉ FRÉDÉRIC (1895–)

For his contribution toward a new era in heart research, André Frédéric Cournand, French-U.S. physician and physiologist, shared the 1956 Nobel Prize in medicine or physiology with Werner T. O. Forssmann and Dickinson W. Richards. The three men were honored for perfecting cardiac catheterization, which resulted in more accurate diagnoses of heart defects. (*See* Werner Theodor Otto Forssmann; Dickinson Woodruff Richards.)

Cournand was born in Paris, France, and educated at the University of Paris. He served in the French army in World War I. After receiving his doctorate in 1930, he went to New York City to study diseases of the chest. He secured a residency in the tuberculosis service of the Columbia University division at Bellevue Hospital. There he met Richards, and they collaborated for more than twenty-five years on research into processes and diseases of the heart and lungs.

Seeking more precise ways to measure cardiac and pulmonary function, they learned of Forssmann's experiment. Forssmann had opened a vein in his arm, inserted an opaque catheter until it reached the right atrium of his heart, and then had an x-ray photograph made of his chest. Cournand and Richards perfected this method of investigating.

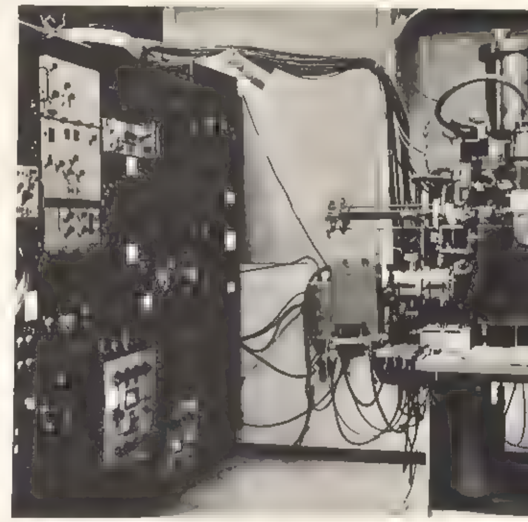


André Cournand

Cournand joined the faculty of the Columbia University College of Physicians and Surgeons in 1934, becoming a full professor in 1951. He was elected to the National Academy of Sciences in 1958. He became a naturalized U.S. citizen in 1941.

CREWE, ALBERT VICTOR (1927–)

With the aid of a scanning electron microscope developed by British-born U.S. physicist Albert Victor Crewe and his colleagues, scientists were able to see individual atoms of uranium and thorium in 1970 for the first time. The new technique makes it possible for a single atom to be isolated and photographed. Before the new instrument was developed, the smallest collection of atoms that could be seen was about ten.



Using a scanning electron microscope of their own invention, Albert Crewe and his co-workers were able to view images of uranium and thorium atoms.

Albert Crewe

Crewe, who became a U.S. citizen in 1962, was born in Bradford, Yorkshire, England. In 1951 he received his doctorate from the University of Liverpool, where from 1950 to 1955 he was assistant lecturer and then lecturer. While there he began a research program in cosmic rays. In collaboration with W. H. Evans of the university, he built the first diffusion cloud chamber in the British Isles.

At about the same time, University of Chicago scientists were trying to extract a beam of proton particles from a cyclotron, or atom smasher. Learning about Crewe's work, the Chicago group in 1955 invited him to its campus.

In 1958 Crewe became director of the particle accelerator division at the Argonne National Laboratory near Chicago, and in 1961 he became director of the entire research complex. It was at Argonne that his interest in electron microscopy was intensified.

Crewe resigned from the laboratory in 1967 to devote full time to research and teaching at the University of Chi-

cago. He was made a professor in the Department of Physics and the Enrico Fermi Institute.

CRICK, FRANCIS HARRY COMPTON (1916–)

The work of the British biochemist and physicist Francis Harry Compton Crick has been called the most important development in twentieth-century biology and has had tremendous impact upon the science of genetics. For his research and discoveries regarding the molecular structure of nucleic acids, he shared the 1962 Nobel Prize in medicine or physiology with J. D. Watson and M. H. F. Wilkins. (*See* James Dewey Watson; Maurice Hugh Frederick Wilkins.)

In connection with his research on the molecular structure of nucleic acids, Francis Crick, together with James D. Watson, worked out a model of the proposed structure of the DNA molecule showing the spatial relationships of the atoms. Alternating phosphate and sugar components running diagonally down the molecule formed a double helix.

Along with Watson, Crick worked out a hypothetical model for the deoxyribonucleic acid (DNA) molecule. It was already known that physical characteristics were inherited through nucleic acids and that the DNA in chromosomes was a vital element to all life. Before the investigations of Crick and Watson, however, the way in which DNA reproduced itself was a mystery. After studying the data accumulated by Wilkins on x-ray diffraction, Crick and Watson came up with a workable hypothesis in 1953.

They proposed that the DNA molecule was a double helix and that replication occurred when the double helix unwound and the four nitrogenous bases already found in nucleic acids paired off: adenine to thymine, guanine to cytosine. Subsequent experimentation seemed to confirm the accuracy of their model, which is now generally accepted among biochemists. After completing this phase of his work, Crick, along with his colleagues at Cambridge, continued to investigate other aspects of the genetic code.

Crick was born at Northhampton, England, and educated at University College in London and at Cambridge. After working for the British Admiralty on radar research and explosive-mine development during World War II, he obtained his doctorate from Cambridge in 1953.

In 1949 he became a member of the staff of the Medical Research Council Laboratory of Molecular Biology at Cambridge, interrupting his stay there in 1953–1954 to work at the Protein Structure Project, Polytechnic Institute of Brooklyn, New York. During 1959 and 1960 he visited the United States to lecture at Harvard University, the Rockefeller Institute, and Johns Hopkins University, Baltimore, Maryland.

CURIE, IRÈNE. See Joliot-Curie, Frédéric and Irène.

CURIE, PIERRE (1859–1906) and MARIE (1867–1934)

Pierre and Marie Curie were a man and wife whose discovery of radium revolutionized theories about the observable universe. They shared in the 1903 Nobel Prize in physics, and Marie became the first person to win two Nobel awards when she was honored with the 1911 prize in chemistry.

Antoine Becquerel had discovered that uranium emits rays that penetrate several thicknesses of heavy black paper and

Throughout their marriage (189[illegible]–1906), Pierre and Marie Curie pursued scient[illegible] studies to-

affect a photographic plate on the other side. Intrigued by this phenomenon, Marie Curie began to study other elements and minerals for the same property that Becquerel had found in uranium. She discovered that the element thorium is also radioactive. Turning her attention to pitchblende, an ore of uranium, she found that its radioactivity is several times that of the uranium it contains; Pierre joined in her studies to find the unknown substances responsible. In 1898 they announced the discovery of two new elements, which they named polonium and radium.

Pierre concentrated on the physical properties of radium, while Marie sought to obtain pure radium in the metallic state. After working four years in the shed that was their laboratory, Marie produced radium chloride. In 1903 she received her doctorate, she and Pierre were honored with the Davy Medal of the august British Royal Society, and the couple shared the Nobel Prize with Becquerel for discovering radioactivity.

Pierre Curie was born in Paris. He received his early education from his father, a physician. Pierre showed a deep interest in mathematics and a particular aptitude for spatial geometry. In 1878 he became a laboratory assistant at the Sor-

gether, and i[illegible] hey announced their discovery of th[illegible] polonium and radium.

bonne. There he carried out his first work on the calculation of the wavelength of heat waves. He obtained his doctorate in 1895 by showing that magnetic properties disappear at a certain critical temperature, which is still known as the Curie point.

When Pierre met Marie, he was chief of laboratory work at the School of Physics and Chemistry in Paris. He had made important studies of crystals, including the discovery, in 1880, of the piezoelectric effect, a phenomenon by which an electric voltage is produced in certain crystals when pressure is applied or by which an applied voltage causes a crystal to change dimensions. Crystals with piezoelectric properties form an essential part of electronic devices for the recording or reproduction of sound.

In the course of his studies of radium, Pierre proved that its rays are made up of particles electrically positive, negative, and neutral. He also observed the physiological effects of radium—opening the way to radium therapy.

In order to continue his work with Marie, Pierre refused a chair at the University of Geneva, Switzerland. He was appointed lecturer at the Sorbonne in 1900 and professor in 1904. In 1905 he was elected to the Academy of Sciences. On April 19 of the following year, Pierre Curie was run over by a horse-drawn wagon in a Paris street. He died instantly. Besides Marie, he left two small daughters, one of whom became another Nobel Prize winner. After his death Marie intensified her efforts to complete the scientific work they had undertaken together.

Marie Curie was born Manya Sklodowska in Warsaw, Poland. Her father was a physics teacher, and her mother was principal of a girls' school. At the age of sixteen Marie won a gold medal upon completing her secondary education. She taught and worked as a governess and helped pay the expenses of her brother and sister who had gone to Paris for advanced training. When she had the bare minimum saved for her own higher education, Marie went to Paris in 1891 and entered the Sorbonne. Three years later she met Pierre Curie, and they were married on July 26, 1895. Soon their scientific achievements drew the admiration of the world.

A month after Pierre's fatal accident, Marie was appointed to fill the professorship left vacant by his death. Thus, she became the first woman to teach at the Sorbonne. In 1908 she was appointed professor in her own right.

Marie later served on the staff of the Radium Institute in Paris, which became a center for research in nuclear physics and chemistry. She was elected to membership in the Academy of Medicine in 1922. When she was at the height of her fame, she studied the chemistry and the medical applications of radioactive substances.

Marie lived to see the Curie Foundation develop in Paris and the inauguration in Warsaw of the Radium Institute, of which her sister became director; but she died a year before her daughter and son-in-law were awarded the family's third Nobel Prize. Marie's death resulted from leukemia, thought to have been induced by long exposure to intense radiation. (*See* Frédéric and Irène Joliot-Curie.)

CUVIER, BARON GEORGE LÉOPOLD CHRÉTIEN FRÉDÉRIC DAGOBERT
(1769–1832)

The French naturalist George Léopold Cuvier, who originated the natural system of animal classification, is often referred to as the Father of Comparative Anatomy. For his pioneering studies of fossils, he is also credited with being the founder of paleontology.

His work in comparative anatomy led to his interest in the natural classification of animals. He grouped related classes by dividing the animal kingdom into four phyla: Vertebrata, Mollusca, Articulata, and Radiata. His system of classification stressed the internal structures of animals rather than their superficial characteristics. Even though modern science recognizes many more phyla, Cuvier's principles have continued to guide biologists and taxonomists. His principles were also applied by Augustin Pyrame de Candolle to the natural classification of plants. (*See* Candolle, De, Family.)

Cuvier did not limit his system of classification to extant members of the animal kingdom but expanded it to also include animals that were known only in fossil form. He grouped these extinct forms of life under his four basic phyla and their subgroups. In 1796 he discovered a fossil that he identified as an extinct type of elephant. In 1812 he exhibited a fossil of a flying reptile, which he called a pterodactyl. He published the results of his research on living and fossil animals in *Le Règne animal distribué d'après son organisation* (1817).

In spite of his scientific acumen, Cuvier was somewhat hampered in his research by a devotion to the literal interpretation of the Book of Genesis. He constantly sought to reconcile his scientific discoveries with the version of the Creation as presented in the Bible, and throughout his life he was opposed to any theory of evolution.

Cuvier reasoned that the Earth had periodically been destroyed by floods and that each time after the waters receded life began anew. He proposed that there had been four catastrophic floods, the last being the one described in Genesis.

Cuvier was descended from a family of French Huguenots who had fled to Switzerland. His father was a Swiss citizen but was serving in the French army when Cuvier was born at Montbéliard, France. Cuvier was educated at the Academy of Stuttgart; and while working as a tutor in a family of French Protestant aristocrats, he developed an interest in science.

In 1795 he was appointed assistant to the professor of comparative anatomy at the Museum of Natural History in Paris. There he became interested in comparing the anatomy of one species with that of another. Also in 1795 he became a member of the newly formed Institut National.

He began lecturing at the École Centrale du Panthéon in 1796, and in 1799 he was appointed professor of natural

history at the Collège de France. In 1802 he was made titular professor at the Jardin des Plantes. Between 1800 and 1805 he published his five-volume *Leçons d'anatomie comparée*, in which he presented his theory of the correlation of parts in animals.

George Cuvier

Being one of the most eminent scientists in Europe, Cuvier became involved with the various French governments that came and went during his lifetime. In 1802 he was made an inspector of education. Napoleon appointed him to the council of the Imperial University in 1808. In 1819, after the Bourbons had returned to power, he was appointed chancellor of the Imperial University. He was also a member of the cabinet of Louis XVIII. Cuvier did not get along with the next French ruler, Charles X, and so went into exile. When Louis Philippe ascended the throne, however, Cuvier was once again on good terms with the government. He was made a baron in 1831 and a year later was appointed minister of the interior, but he died in Paris before he could assume office.

DAGUERRE, LOUIS JACQUES MANDE
(1787–1851)

The first practical method for photographically reproducing images was developed by a French theatrical-scenery painter, Louis Jacques Daguerre. He gave the new invention his name, calling it the daguerreotype. It was produced by the action of light on a copper plate that had been coated with silver salts. The light part of an image darkened the salts, and the darker parts left the salts unchanged; in this way a permanent image was formed. Even though by modern standards the daguerreotype process was slow and crude, it was undoubtedly one of the most popular inventions of the mid-1800s.

Daguerre, the son of a magistrate's court official, was born at Cormeilles. In 1804 he was apprenticed to the chief designer at the Paris Opera. He worked as an assistant to the panorama painter from 1807 to 1816, when he became an independent stage designer.

Along with Charles-Marie Bouton he developed the diorama, consisting of large paintings done on semitransparent linen. Real objects were blended with the painted background, and the use of direct and reflected light caused changing effects. A diorama theater was established in Paris in 1822 and in London the following year.

The preliminary sketches for these dioramas were made with the camera obscura, a dark chamber with a small opening through which sunlight could enter and project an image of objects outside the chamber onto a screen. This technique led to Daguerre's interest in producing, by chemical fixation, a permanent picture.

Since 1814 a French physicist named Joseph Nicéphone Niepce had been trying to take permanent pictures by the action of sunlight. After learning of each other's efforts, Daguerre and Niepce joined forces in 1829 and worked together until Niepce's death [illegible] 1833. Daguerre then continued th[illegible] work alone and eventually developed t[illegible] daguerreotype process.

It was already known th[illegible]ight could darken silver compounds[illegible] 1831 Daguerre discovered the ligh[illegible]sitivity of silver iodide. Then in 183[illegible] found that a latent image could be[illegible]eloped by mercury vapor. In 1837 [illegible]rmanently fixed pictures with sodium[illegible]ride; after 1839 he used sodium thios[illegible]te.

In 1839 he communicat[illegible]s discovery to the Academy of Scienc[illegible] For his invention he was made an[illegible]cer of the Legion of Honor and was[illegible]nted membership in several foreig[illegible]demies. In exchange for the daguerr[illegible]pe process the French government [illegible] Daguerre an annual pension of Fr. [illegible]0. The son of Niepce was given an [illegible]uity of Fr. 4,000. Five days before th[illegible]rench gov-

Louis Daguerre's discovery that exposing an iodized silver, or a silver-covered copper, plate in a camera would result in an image if the plate was fumed with mercury vapor and fixed in a solution of common salt became known as the daguerreotype process.

Louis Daguerre

ernment made the details of the process public, howev.r, Daguerre obtained a patent in E... nd. In 1840 he retired to an estat... ...y-sur-Marne, near Paris, where he li... or the remainder of his life.

DALE, SIR H... HALLETT
(1875–1968

For disco... elating to the chemical transmission ... erve impulses, Henry Hallett Dal... sh physiologist, shared the 1936 N... Prize in physiology or medicine. T... winner was his long-time friend ... Loewi, the German pharmacolog... See Otto Loewi.)

Dale was ... n London, England. He received hi... l degree from Cambridge Uni... n 1909. Earlier, while doing resea... under the direction of Ernest H. S... g, he met Loewi, who also was wo... with the eminent physiologist.

In his ear... research Dale was concerned wit... mposition and effects of ergot of ... hile studying this fungus, Dale is... d in 1914 a compound known as a... holine. Its effects on organs of th... ly were similar to those produced b... es of the parasympathetic syste... r Loewi discovered in 1921 that ... al phenomena are involved whe... nerves are stimulated, Dale show... ertinent chemical substance to b... choline.

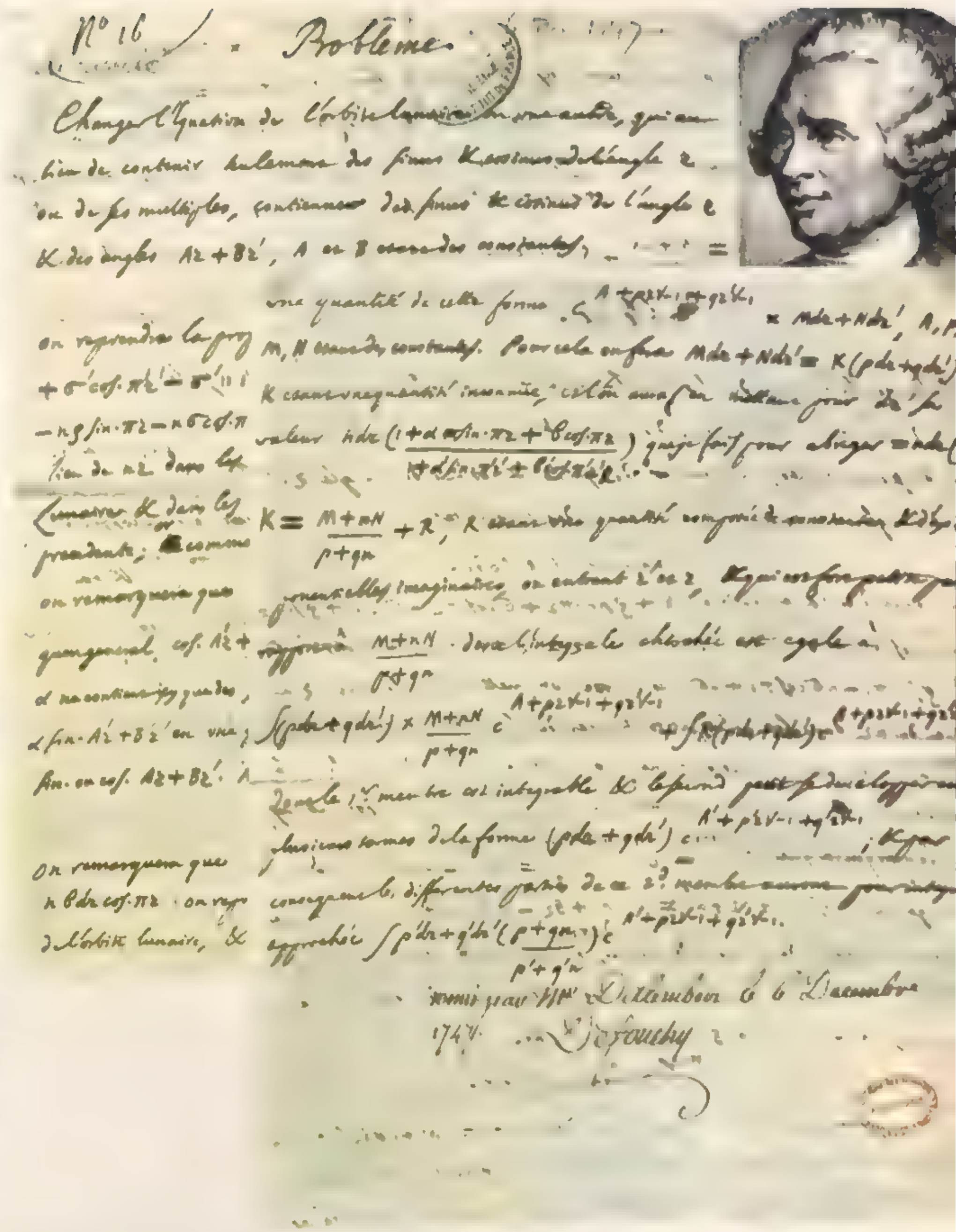
From his ... with ergot, Dale went on to stud... action of histamine, a constituent ... got extracts, upon surgical shock ... naphylaxis—hypersensitivity to a ... r other causative agent after sensit... n by previous contact. His research ... d important applications in practical medicine.

Dale was appointed head of the Department of Biochemistry and Pharmacology of the Medical Research Council in 1914. From 1928 to 1942 he directed the National Institute for Medical Research. He was president of the Royal Society from 1940 to 1945. He served also as president of the British Association for the Advancement of Science and of the Royal Society of Medicine.

During World War II, Dale was chairman of the Scientific Advisory Committee to the British cabinet and a member of the Advisory Committee on Atomic Energy. Dale was knighted in 1932 and was awarded the Order of Merit in 1944.

D'ALEMBERT, JEAN LE ROND
(1717–1783)

The French mathematician Jean le Rond D'Alembert not only made important contributions to the science of mechanics but also aided Denis Diderot in editing the famous *Encyclopédie*. In addition, he spent time writing on the philosophy of science and showed great interest in music.



Jean D'Alembert was the first to recognize that forces on a moving body can be expressed by equations, two of his important contributions being his theory of vibrating strings and the general solution for the wave equation, both accomplished in 1747.

D'Alembert was the illegitimate son of aristocrats, who abandoned him near the Church of St. Jean le Rond soon after his birth in Paris. He took his name from this church. The child was taken in and raised by a glazier and his wife. Nevertheless, his real father, the Chevalier Destouches, contributed to his support.

He received his early education from the Jansenists at Mazarin College. Later he had difficulty in choosing a profession. First he studied law at the University of Paris and was admitted as an advocate in 1738, but he never practiced. Instead, he took up the study of medicine. In about a year, however, he decided to pursue mathematics. In 1741 he was admitted as a member of the Academy of Sciences.

After he had made a reputation for himself, his aristocratic mother, Madame de Tencin, tried to claim him as her own. D'Alembert refused to recognize her, stating that the glazier's wife was his mother.

D'Alembert made several important

contributions to mathematics. In calculus he clarified the concept of limits and introduced the idea of different orders of infinities. He was the first to explain theoretically the phenomenon that occurs when a body passes from one fluid to another, denser fluid in a direction not perpendicular to the surface separating the two fluids.

He is perhaps best known for his mechanical principle known as D'Alembert's principle, which he presented in *Traité de dynamique* in 1743. D'Alembert applied this principle to a number of problems, such as the theory of equilibrium and the motion of fluids. Then he went on to discover the calculus of partials and devoted himself to gravitational theory. Using his principles, he solved the problems of the precession of the equinoxes and also produced an explanation regarding the nutation of the Earth's axis.

In 1747 D'Alembert published his theory of vibrating strings and gave the general solution for the wave equation. Between 1754 and 1756 he perfected the solution to the problem of the perturbation of the planets. He wrote the introduction to the *Encyclopédie* and contributed several literary, as well as mathematical, articles.

DALÉN, NILS GUSTAF (1869–1937)

Nils Gustaf Dalén, a Swedish inventor, won the 1912 Nobel Prize in physics for a device that automatically kindles and extinguishes gas beacons. It has been especially useful in unmanned lighthouses.

Dalén was born in Stenstorp. He studied engineering at Göteborg and later in Zürich, Switzerland. Early in his career he invented hot-air turbines, automatic milking equipment, and other machinery. In 1906 he became chief engineer of a company that was promoting in Sweden dissolved acetylene, a French invention. Three years later Dalén was appointed managing director of the company.

While several forms of automatic lighting equipment were used in the late nineteenth century, Dalén's acetylene gas flashing apparatus, which he invented in 1906, made possible the modern unattended lighthouse. For unwatched lights where electricity is not available, the usual illuminant still is dissolved acetylene gas. The lights are controlled by sun valves, such as Dalén's, which open and close the gas supply.

Among Dalén's other inventions was a porous filler for acetylene tanks that eliminated the danger of explosion. Dalén himself was blinded by an explosion during an experiment in 1913, but he continued to conduct his experiments until his death.

DALTON, JOHN (1766–1844)

The English chemist and physicist John Dalton did pioneering work in the field of meteorology, made important observations about the behavior of gases, and gave the first detailed description of color blindness, sometimes called Daltonism. (Both he and his brother were color blind.) But most importantly he is remembered for presenting the first quantitative atomic theory.

John Dalton

Dalton, the son of a poor weaver, was born at Eaglesfield, near Cockermouth, Cumberland. He was raised in the Quaker faith and educated at home and at the Quaker school in Eaglesfield. The schoolmaster, being interested in meteorology, did much to involve young Dalton in the study of weather conditions. In 1787 Dalton began keeping a daily record of weather conditions, and he continued the practice for fifty-seven years, until his death. His meteorological diary contained more than 200,000 observations. In 1793 he published *Meteorological Observations and Essays*, containing commentaries on atmospheric phenomena and information on how to make and use meteorological instruments. In this work he also presented a theory stating the electrical origin of the aurora borealis (northern lights).

At the age of twelve Dalton began teaching at the local Quaker school, and in 1781 at the school in Kendal, where he remained until 1793. While at Kendal he was influenced by John Gough, a blind mathematician. Through the efforts of Gough, Dalton was appointed teacher of mathematics and natural philosophy at New College in Manchester. He settled in Manchester and lived there for the remainder of his life. In 1799 he resigned from New College and supported himself by giving lectures and tutoring. When the government granted him a pension in 1833, he b[illegible]ame completely free to devote his ti[illegible] to scientific investigation.

In Manchester, Da[illegible] fell in with a community of scien[illegible] scholars who had founded the [illegible]ster Literary and Philosophical S[illegible] Dalton joined this society in 1794 [illegible] as later given space for his researc[illegible] a house that the society purchase[illegible] he house and most of Dalton's re[illegible] re destroyed in a World War II [illegible]

As a natural outgro[illegible] of his interest in atmospheric gases [illegible] ton began investigating gases in ge[illegible]l. In 1801 he presented his law of [illegible] ial pressures, which states that the [illegible] ure of a mixture of gases is the su[illegible] the pressure that each component g[illegible] would exert if that gas alone were o[illegible] ing the same space at the same tem[illegible] ture. In 1803 he discovered the law [illegible] multiple proportions and presente[illegible] first table of atomic weights.

Dalton subscribed [illegible] view that gases are composed of [illegible], indivisible particles and eventu[illegible] applied this idea to all matter. Rec[illegible] ng the similarity between his conc[illegible] d that of the ancient Greek philoso[illegible] Democritus, Dalton chose to use [illegible] ocritus' term *atoms* to describe the[illegible] ny particles. Unlike the ancient G[illegible] ks, however, Dalton maintained tha[illegible] e atoms of various elements differ [illegible] cause of the differences in their masses, or weights. This was the beginning of the modern atomic theory. (*See* Democritus.)

Dalton's other chemical works included an investigation of the force of steam and the expansion of gases by heat. Between 1808 and 1827 he published in three parts his *New Systems of Chemical Philosophy*, detailing his ideas about atoms.

Kept busy by his scientific pursuits all of his life, Dalton never married. Because of his Quaker background he was a modest man who shunned fame and public recognition. Nevertheless, he received many honors in his lifetime. In 1816 he was elected a corresponding member of the French Academy of Sciences, and in 1830 he became one of the eight foreign associates. He was elected to the Royal Society in 1822 and was the first to receive the society's Royal Medal. Also, the universities of Edinburgh and Oxford bestowed honorary degrees on him. When he died, about 40,000 people came to pay their respects, and more than 100 carriages made up his funeral procession.

DAM, CARL PETER HENRIK (1895–)

Carl Peter He[illegible]rik Dam, Danish biochemist who id[illegible]tified vitamin K, was awarded a share [illegible] the 1943 Nobel Prize in physiology or [illegible]dicine. His co-winner was Edward A[illegible]oisy, whose research group subsequ[illegible] isolated vitamin K, which is ess[illegible]or the clotting of blood. (*See* E[illegible] Adelbert Doisy.)

Dam was bo[illegible] educated in Copenhagen. After [illegible]raduation from the Copenhagen [illegible]chnic Institute in 1920, he taugh[illegible]s School of Agriculture and Vete[illegible] Medicine. He was appointed ass[illegible] professor of biochemistry in [illegible] post that he held until World W[illegible]

Carl Dam

In experim[illegible]een 1929 and 1934 Dam and his [illegible]gues noted a deficiency diseas[illegible]s that were fed a synthetic diet. [illegible]ns developed small hemorrhages [illegible] the skin and inside the muscles, [illegible]e clotting time was extremely long [illegible] showed in 1934 that the missing fac[illegible] their diet was a fat-soluble vitami[illegible] called it vitamin K (for the Germa[illegible] *Koagulation*). Biochemists led by Dois[illegible] isolated the vitamin within a few years and worked out its chemical formula. Its importance to blood clotting made it a valuable aid in surgery and in other circumstances involving the threat of hemorrhage.

Dam contributed later to other aspects of vitamin research and to the biochemistry of fats and sterols, notably cholesterol. In 1940, while he was lecturing in the United States and Canada, Germany invaded Denmark. Dam remained in the United States and pursued his work during the war. He was senior research associate at the University of Rochester, New York, from 1942 to 1945 and associate member of the Rockefeller Institute for Medical Research in New York City the following year. After the war, he returned to Copenhagen, where in absentia he had been appointed professor of biochemistry at the Polytechnic Institute in 1941. From 1956 to 1963 he headed the biochemical division of the Danish Public Research Institute.

DANA, JAMES DWIGHT (1813–1895)

One of the most prolific writers in his field was the U.S. geologist, mineralogist, and zoologist James Dwight Dana. From 1835 until his death he published 214 different works. He also made a considerable contribution to the knowledge of the geology and zoology of areas in the Pacific Ocean.

Dana was born at Utica, New York, and educated at Yale, graduating in 1833. For two years he taught mathematics to midshipmen in the navy, and in 1836–1837 he was an assistant in the chemical laboratory at Yale.

Then for four years Dana served as geologist and mineralogist on the Wilkes exploring expedition sent by the U.S. government to the South Pacific. He summarized his work on the expedition in *Zoophytes* (1846), *Geology of the Pacific Area* (1849), and *Crustacea* (1852–1854). Among his more notable works written later in his life were *Manual of Geology* (1862), *Textbook of Geology* (1864), *Corals and Coral Islands* (1872), and *Characteristics of Volcanoes* (1890). His *System of Mineralogy*, published in 1837, is considered to be his most outstanding work.

In 1840 Dana became editor of the *American Journal of Science*. He was professor of natural history at Yale from 1849 until 1864, when he was appointed professor of geology and mineralogy. He held that post until 1890.

Dana received honorary degrees from the universities of Edinburgh and Munich and from Harvard University. In 1854 he was elected president of the American Association for the Advancement of Science. He was awarded the Woolaston Medal of the Geological Society of London in 1872, the Copley Medal of the Royal Society in 1877, and the Walker Prize of the Boston Society of Natural History in 1892.

DARWIN, CHARLES ROBERT (1809–1882)

The theory of evolution through natural selection was formulated by the English naturalist Charles Robert Darwin. His most important book, *On the Origin of Species by Means of Natural Selection*, was greeted by the scientific world with a storm of controversy but eventually had a profound effect on man's ideas about his origins.

Darwin was born in Shrewsbury, Shropshire, England, the son of a physician. He was educated at Shrewsbury School and then went to Edinburgh University to study medicine. A medical career did not seem feasible to him, and so he studied theology at Christ's College, Cambridge. He received his degree in 1831 but did not seek honors.

His career as a naturalist got under way with the voyage of the H.M.S. *Beagle* from 1831 to 1836. As the ship's naturalist he had ample opportunity to study various animal species on Cape Verde and other Atlantic islands, Tahiti, New Zealand, and the South American coasts. On the Galápagos Islands, for example, he studied birds; he noted that fourteen different species of finch existed on the island and that they were of different sizes and of different eating habits. It appeared to Darwin that one species of finch had migrated from the mainland originally but had evolved into other species to fit the changing conditions encountered in its new home. He pub-

Charles Darwin

Charles Darwin's observations of the birds, especially finches, of the Galápagos Islands contributed to his theory of evolution, published more than twenty years later.

lished his observations as *A Naturalist's Voyage on the Beagle* in 1839.

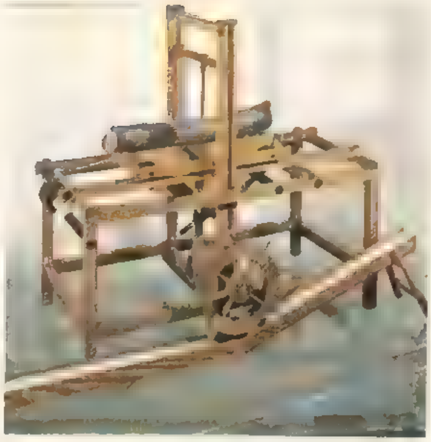
From 1838 to 1841 Darwin served as secretary of the Geological Society. There he became closely associated with the geologist Sir Charles Lyell, whose principle of uniformity had been important to Darwin's thinking.

A book that had a strong influence on Darwin was Thomas Robert Malthus' *Essay on the Principle of Population.* Malthus saw life as a struggle, with the population growing faster than the food supply, and felt that the population would be reduced through war, famine, or disease. Applying Malthus' ideas to his own, Darwin felt that the weaker species would fall by the way in the competition for food. Only the strong would survive in this process of natural selection.

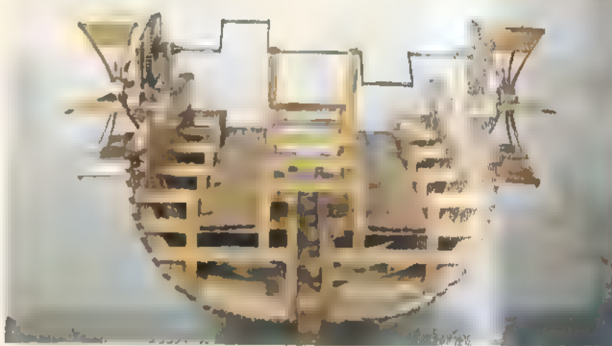
In 1856 Darwin started writing his book on evolution. He was only halfway through his work when the naturalist Alfred Russel Wallace sent him a copy of his own manuscript on natural selection. On the advice of Lyell and other friends, Darwin quickly wrote a summary of his projected work and sent it, together with Wallace's work, to the Linnean Society. Both essays were published in the *Journal of the Linnean Society* (Zoology) in 1858.

Darwin's great work, usually referred to simply as *The Origin of Species*, was published on November 24, 1859. The first printing of 1,250 copies was sold out on the day of publication. In the early parts of the book, Darwin unfolded his theory, which he then substantiated with factual material from such fields as paleontology and comparative anatomy.

In the great controversy that surrounded Darwin's theory, T. H. Huxley was one of his greatest champions. Many resisted Darwin's theory because they felt it contradicted their religious beliefs.



Leonardo da Vinci



Representative of Leonardo da Vinci's many projects that, because of their exactness and detail, have been copied and exhibited as working models by many museums are a hydraulic saw that could advance the material to be cut, a machine with movable wings operated by pedals, a ship propelled by wheels, and a glider with maneuverable wings.

DA VINCI, LEONARDO (1452–1519)

The Florentine Leonardo da Vinci was as great an artist as he was a scientific and technical genius. He excelled in everything he turned to, and this despite the fact that he was competing, not with secondary figures, but with such masters as Michaelangelo and Raphael.

As for his works of hydraulic engineering and fortification, no contemporary engineer approached him either in boldness of achievement or in the ability to realize such innovatory constructions with the manual methods then available.

In all the branches of science to which he turned his attention he was ahead of his time by at least a century, with his intuition of the first principle of dynamics and with his use of experimentation, which was to lay the foundations of much of science as we now know it. The sphere in which he ranged widest, however, displaying brilliant imagination, was that of machines. Here there is scope for controversy, for it is not usual to call a person an inventor unless he has successfully developed the product of his genius. In Leonardo's case there are presented a whole series of ideas, some of which—like his hydraulic constructions—were fully executed, while others—like certain of his machines for working metal—were only partly developed, and still others remained mere ideas, even if well-outlined ones. The ideas that were not fully developed remained in embryo chiefly because something was lacking in the technology of the times that prevented them from being developed.

Leonardo was born in the village of Vinci, Italy, on the western slope of Mount Albano, between the plains of Florence and Fucecchio. The family members were by tradition notaries, except for Leonardo's grandfather Antonio. They were not a well-to-do family, and only Leonardo's father, Piero, managed to get rich, and then only after he moved to Florence with his family. Leonardo's mother was Caterina, probably a peasant girl who worked in Piero's house. In the same year that Leonardo was born, his parents got married but not to each other: Caterina married a certain Attac-

cabriga di Piero del Vacca da Vinci; and Piero married Albiera Amadori, the first of his four wives. Leonardo, whom his father never legitimatized for some unknown reason [illegible] rew up in his father's house, surrounded by the affection of his grandfather an[illegible] his stepmother Albiera.

When, prob[illegible] in the early 1460s, the Vincis move[illegible] Florence, Leonardo was sent to [illegible] abacus school, where those childre[illegible] did not need a real cultural prep[illegible], being destined for commerce or [illegible] trade, were given a smattering o[illegible] on. This at least had been Piero's i[illegible] until, astounded by his son's inte[illegible] precociousness and, especially, b[illegible] ceptional artistic talent, he show[illegible] undle of Leonardo's drawings to [illegible] riend Andrea Cioni, called Verro[illegible] an established goldsmith, sculpt[illegible] painter. Verrocchio enthusiasticall[illegible] k the boy, who was then thirteen, [illegible] his workshop, where Leonardo ha[illegible] chance to meet the most illustrio[illegible] ple of Florence, not only artists b[illegible] o authors and scientists. Leonard[illegible] ayed with Verrocchio until 1476, aft[illegible] hich he worked alone.

Although h[illegible] ly education and activities had [illegible] sentially artistic, his desire to per[illegible] means of expression and style g[illegible] led him to study reality in all it[illegible] ous aspects. Mixed in among his d[illegible] gs are notes on perspective, an[illegible] zoology, botany, geography, geo[illegible] architecture, and mechanics. The[illegible] are written in that enigmatic m[illegible] writing of his that resembles certa[illegible] ental scripts and that, though proba[illegible] aused by just his left-handedness, w[illegible] to prove useful in enabling him to k[illegible] p his manuscripts secret.

His scientific studies were becoming increasingly important to him; and looking for a position in which he could use his knowledge of civil and military engineering, he entered the service of Ludovico il Moro, the ruler of Milan, in 1482.

The most peaceful years of his restless existence were spent in Milan. Ludovico's first request was to have a colossal equestrian statue of his father, Francesco Sforza, erected; but Leonardo never finished it because the enormous clay model was destroyed by the invading French troops in their eagerness to do away with all traces of the old rulers of the city. Although he was not rich (he was never rich at any time in his life), he was at least secure in Milan from the poverty he had suffered in Florence, and could count on general esteem and regard as well. He was never rich because he was never capable of completing a painting quickly. Unlike his much less skilled Tuscan colleagues, whose works were in part either composed or finished off by poorly paid apprentices, Leonardo worked on his own without any help; and every painting he did served as a pretext for carrying out interminable researches into perspective, anatomy, color, and shading. One might almost say that his painting was a by-product of other researches, for which he, of course, did not get paid and which were so time comsuming that it took him years to complete works.

Leonardo was a good-looking man with a virile bearing. It is said that one of his usual tests of strength was to straighten a horseshoe with his bare hands and then bend it back to its normal shape. He was also refined, however, and able to converse with great charm, which soon made him much sought after at court. Not only was he an entertaining talker, but he was also often called upon to arrange festivities and entertainments that would astound the guests by some unusual trick. One of these was the jest of gathering a few guests together in a room and then, through pipes that extended to the next room into bellows, blowing up enormous balloons so that his friends were gradually driven into a space that got smaller and smaller. More polished was his playing, sometimes by improvisation, of delightful music composed by himself (some of these pieces have recently been put together again) on a cithara that he had made, using a horse's skull as the sound box.

Leonardo, however, was not after society life. Eternally restless and dissatisfied, he was untiring in his exploration of one field after another. The war between Milan and Venice (1483–1484) had induced him to write to Ludovico putting forward his many war devices; and the following year, when Milan was devastated by the plague, he seized the opportunity to present the prince with plans for constructing a more rational city.

Leonardo's stay in Milan was brought to an abrupt end in 1499 when the city was conquered by the French. The decisive cause of his departure was probably the defeat of Ludovico. Leonardo then went to Mantua and on to Venice.

The following year, 1500, he returned to Florence and was caught up by fresh projects and scientific studies. He received many commissions for paintings but did not execute them all. For a brief time he left to be in the service of Cesare Borgia but soon went back to Florence. There once again he met with malice, envy, and disappointment, especially because of Michelangelo but also because of some of his unorthodox attitudes that revived old charges of irreligion; thus, it was with pleasure that he in 1506 again returned to Milan, now under the French.

Leonardo had not ended his wanderings, however. Because of the confused political situation, he accepted Leo X's invitation to go to Rome in 1513, but the ever present influence of Michelangelo and Raphael induced him to leave Italy once and for all and go to France, his last haven. Leonardo spent his last years as the guest of Francis I, a great admirer of his, at the Castle of Cloux near Amboise; they were tranquil years, though his right hand became paralyzed (fortunately, he was left handed).

Many of Leonardo's works of art were destroyed, lost, dispersed, or ruined, while his scientific works long remained unknown and were published only centuries later, when they were no longer able to offer anything new.

Two complete treatises—on painting and on hydraulics—and a compendium on the flight of birds have been extracted from Leonardo's manuscripts, which were more than once disarranged and then put in order again. He dealt in a detailed way with a countless number of subjects, however, from optical mechanics to anatomy, from astronomy to meteorology, from geology to botany, to mention only a few. The first principle of dynamics, by which a body remains immobile or continues its uniform rectilinear motion if not subjected to any force, was Leonardo's work. This principle alone would suffice to classify him as an outstanding physicist, especially when it is known that his contemporaries were still spellbound by Aristotle's theories, but this was not the only way in which Leonardo anticipated mechanics. In all his reasonings he proclaimed and followed a strict principle of cause and effect, considering, for example, the parallelogram resolution of forces as being valid.

Leonardo left many projects that are so exact and detailed that many museums have made working models from them. There are machines for lifting weights and water, for working wood and metals, for driving carts, and for making precision instruments and war engines; industrial machines driven by waterpower; works of civil and hydraulic engineering; and plans for improving towns and cities.

While he was living in Milan, Leonardo took many trips to various parts of Lombardy to make plans for works of land reclamation and irrigation. He was much more fortunate with these works than with his paintings. Part of the Lombardy irrigation system still used today

is the original one Leonardo projected, and his use of locks is still immortalized by constructions preserved in Milan. Upon his return to Florence he was appointed by the republic to continue plans to make the Arno navigable. He also conceived the bold plan, which frightened the Florentines, of raising the Baptistery of St. John so as to utilize a base with steps under it. While in the service of Cesare Borgia he planned fortifications for Piombino and a navigable canal between Cesena and Cesenatico; later, during his second stay in Milan, he worked on the exciting idea of joining Milan and Lake Como by canal. He also executed the system of regulation of the waters of the Grand Canal.

Even more revolutionary and ahead of his time were his anatomical studies and researches. His artistic studies of the nude in themselves reveal a thorough knowledge of anatomy, but Leonardo did not stop here–he also wanted to get to know more about the physiology of the human body.

He carried out (in secret, for fear of anathemas) innumerable dissections of corpses, certainly more than many anatomy professors of that age who founded their teaching and knowledge on the authority of Galen and Avicenna rather than on the evidence of the facts.

Leonardo first established the important biological fact that "the seed of the mother has a power in the embryo equal to the seed of the father." Later he studied the circulatory system at length and also displayed perfect familiarity with the vocal apparatus.

Contradicting the scholastic dogmatism of his time, he stated that the Earth was round and that it moved around the sun. He also gave a correct explanation for earthshine.

His studies had made him realize the fundamental importance of water for all living forms; therefore, he maintained that water must have played an important part during the evolution of the Earth as well. His artistic genius and geometric ability combined to make him a skilled map maker, as shown by the topographic maps he drew up for his hydraulic projects.

That experience is the origin of knowledge had been clear since the time of Aristotle, but the experience referred to was only the superficial one of everyday life and not that gained by scientific experiment repeated in a precise and systematic way under varying conditions. Leonardo was the first upholder of the inductive and experimental method.

It is Leonardo's experiments in the world of flight that have made him best known to the common man. Leonardo's belief in the possibility of flight was based on scientific study. He was the first to perceive the mechanical laws of flight clearly, thanks to his long and careful study of the flight and structure of birds. He realized, above all, that weight is not a hindrance to flight but an essential condition for it.

His first plan was for a model of a flying machine with beating wings driven by the energy of the man stretched out on it; later he limited his experiments to a fixed-wing model for gliding. Then, after fifteen years of experiments and studies, he abandoned not only aeronautics but also aerodynamics. He had made a very important contribution to these sciences, and successive pioneers of aeronautics were always to have something to learn by studying his experiments, even if the new possibilities afforded by building and engine techniques were gradually to direct projects for flying machines toward other forms. Despite the inevitable failure of his plans for flying machines, Leonardo invented the parachute and was the first to think of the helicopter.

DAVISSON, CLINTON JOSEPH
(1881--1958)

By accident the American physicist Clinton Joseph Davisson made his greatest discovery, the diffraction of electrons by crystals. For this work he shared the 1937 Nobel Prize in physics with George Paget Thomson, who independently had made a similar discovery in England. (*See* George Paget Thomson.)

In 1927 Davisson experimentally demonstrated Louis de Broglie's theory about the wave nature of electrons. He was studying the reflection of electrons from a nickel target enclosed in a vacuum tube when the tube accidentally broke. The nickel target became coated with an oxide film and had to be heated for a long time to remove the film. After this process was completed and the nickel was usable as a target again, Davisson noticed that the reflecting properties of the nickel had changed: after heating, it contained a few large crystal surfaces; but before heating, it had contained many small crystal surfaces.

Davisson then isolated a single nickel crystal and used that as a target. Along with his associate L. H. Germer he studied the scattering of slow electrons from a single crystal. He found that the electrons were diffracted, as well as reflected.

Clinton Davisson

Because diffraction is a characteristic of waves, this experiment proved De Broglie's theory.

Davisson was born at Bloomington, Illinois. He began his undergraduate work at the University of Chicago on a scholarship and later attended Princeton University, where he obtained his doctorate in 1911. He worked at the Carnegie Institute of Technology, Pittsburgh, Pennsylvania, until 1917, when he left to work for the Western Electric Company. In 1925 he began working as an electrophysicist at the Bell Telephone Laboratories in New York City. Eventually he became director of the laboratories. Davisson's other notable work was in thermionic emission of clean and oxide-coated metals and with early electron microscopes.

DAVY, SIR HUMPHRY (1778–1829)

During his lifetime the English chemist Sir Humphry Davy exhibited a wide range of interests, from mathematics to philosophy and poetry. Among his friends were the English "lake poets"–Coleridge, Southey, and Wordsworth. He won his fame, however, for his discoveries regarding the inhalation of certain gases, for his work in electrochemistry, for his propagation of the scientific method, and for his isolation of potassium and sodium.

Davy, the son of a wood-carver, was born at Penzance, Cornwall. He had little formal education beyond preparatory and grammar school. Instead, after the death of his father, he was apprenticed to a surgeon so that he might make his career in medicine. During his apprenticeship he read Lavoisier's *Traité élémentaire* and began testing Lavoisier's ideas. This inspired Davy to become a chemist. He soon came to disagree with Lavoisier's caloric theory and instead concluded that heat is a form of motion.

After completing his apprenticeship, Davy went to work as an assistant at the

Medical Pneumatic Institution in Bristol, founded to investigate the therapeutic uses of gases. In 1799 he discovered that nitrous oxide, when inhaled, produces an exhilarating effect. Although after this discovery there were some who used the laughing gas to intoxicate themselves for their own amusement, nitrous oxide found genuine medical use as the first chemical anesthetic. Davy also studied the effects of the inhalation of carbureted hydr[illegible] nitrogen, and other gases. On o[illegible] he came close to killing himself [illegible] poisonous gases.

In 1801 he [illegible]n lecturing at the Royal Institution [illegible]don. From 1802 to 1812 he was pro[illegible] of chemistry there. He proved an [illegible] popular lecturer, and his lect[illegible]ctually became important social [illegible]ons attended by London's social[illegible] While at the institution, he did rese[illegible]on voltaic cells, on the process of ta[illegible], and on mineral analysis. In 1805 [illegible] this work he was awarded the Copley Medal of the Royal Society, of which he had become a fellow two years prev[illegible]

Some of [illegible]'s most important work involved el[illegible]ity. In 1806 he made public his [illegible]cal theory of chemical affinity and [illegible] awarded Napoleon's Prize for th[illegible]'s best work in electricity. Althou[illegible]nce and England were at war, D[illegible]ccepted on the ground that a state [illegible]ar existed between the government[illegible] between the scientists.

Proceedi[illegible] his electrical theory of chemical [illegible] Davy constructed a powerful b[illegible]onsisting of more than 250 metal p[illegible] and began experimenting with el[illegible]olysis. In 1807 he succeeded in isolating potassium by passing an electric current through molten potash. Soon afterward he also isolated sodium by electrolysis. In 1808 he isolated barium, boron, strontium, calcium, and magnesium.

In his work with hydrochloric acid Davy proved that some acids are oxygen free and that chlorine is an element. He also explained the bleaching action of chlorine.

After 1811 Davy began to suffer from poor health, and in 1812 his eyes were damaged by a chemical explosion. That same year he resigned from his professorship, was knighted, married a rich Scottish widow, and set out on his first Continental tour. He took along his young assistant, Michael Faraday. It is often said that Faraday was one of Davy's most important discoveries.

While touring Europe, Davy did research on iodine and demonstrated that diamond is carbon. In 1815, after his return to England, he invented the miner's safety lamp. For this service to industry he was awarded the silver and gold Rumford medals and was made a baronet in 1818. From 1820 to 1827 he was president of the Royal Society. After 1823 he spent a great deal of time traveling on the Continent.

Sir Humphry Davy

DE BROGLIE, PRINCE LOUIS VICTOR PIERRE RAYMOND (1892–)

One of the initiators of the new era in physics was Prince Louis Victor Pierre Raymond de Broglie of France, who was awarded the 1929 Nobel Prize in physics for his discovery of the dual nature of electrons. De Broglie arrived at the idea that particles of matter can also behave as waves of energy.

Albert Einstein had discovered that light waves have particlelike properties. De Broglie went further with his idea that not only light waves but also electrons and other particles can behave as waves of energy similar to light waves. His theory, with which he earned his doctorate in 1924, also set forth an important equation to explain the relation between the movement of a particle and the movement of the wave with which it is associated. Experiments by other scientists soon confirmed De Broglie's wave theory of matter, and the concept of matter waves has been dominant ever since in studies of the elements of light and matter.

De Broglie was born at Dieppe, France, to a distinguished family descended from a Piedmontese nobleman who had emigrated to France from Italy in 1643. After obtaining a degree in history at the Sorbonne, De Broglie turned to science. His elder brother Maurice, who was himself an eminent physicist, encouraged Louis to study the new theories of the renowned physicists Max Planck and Albert Einstein.

As professor at the Sorbonne, Louis de Broglie showed exceptional gifts as a teacher. He was best known, however, for his discovery of the wave nature of the electron, for which he received the 1929 Nobel Prize in physics.

In 1913 De Broglie entered the corps of engineers to fulfill his military service. Because of his familiarity with physics, he was given an assignment as radiotelegrapher. In the course of his duties he became interested in theoretical problems of electromagnetic waves. After further study at the Sorbonne he worked for a time in his brother's laboratory, but subsequently he devoted himself entirely to theoretical research. His theory provided the germ of wave mechanics, which Erwin Schrödinger later developed.

De Broglie was appointed professor of theoretical physics at the Henri Poincaré Institute at the Sorbonne in 1928, and in 1932 he became titular professor on the faculty of sciences, a position that he held for thirty years. He was elected a member of the French Academy of Sciences in 1933, becoming its permanent secretary in 1942. From its inception De Broglie was technical adviser to the French Atomic Energy Commission. He became a member of the French Academy in 1944, the Royal Society of London in 1953, the United States National Academy of Sciences in 1948, and the American Academy of Arts and Sciences in 1958.

DE BUFFON, COMTE. See Buffon, Georges Louis Leclerc, Comte de.

DEBYE, PETER JOSEPH WILHELM (1884–1966)

The Dutch-American physicist and chemist Peter Joseph Wilhelm Debye made a number of important contributions in the areas of theoretical and experimental physics. In 1936 he received the Nobel Prize in physics, primarily for his research on the dipole moments of simple molecules. The results of this research were instrumental in the formation of theories of chemical bonding.

Peter Debye

Some of his most notable work involved the theory of electrolytes and electrolytic dissociation in solution. At the time, it was believed that the ionization of electrolytes, such as sodium chloride, was incomplete in solution. Debye contended that ionization was complete, since the electrolytes were completely ionized in crystal form. He reasoned that in solution ionization only appeared to be incomplete because groups of predominantly positively charged ions surrounded each negative ion, and each positive ion was surrounded by predominantly negatively charged ions. He worked out the mathematical basis for this theory in 1923, which came to be known as the Debye-Hückel theory. This theory formed the basis for the modern approach to the study of the properties of solutions.

Earlier he had worked on the x-ray analysis of powdered solids. This was a variation on, and extension of, the crystallography research performed by Sir William Henry Bragg and his son.

Debye's other investigations included the study of the specific heats of solids at low temperatures and the study of the relationship between chemical structure and dielectric properties. Between 1940 and 1950 he studied polymers and developed a method for accurately determining their molecular weights.

Debye was born in Maastricht, the Netherlands. He studied electrical engineering at the Technische Hochschule in Aachen, Germany, earning his degree in 1905. In 1908 he received his doctorate in physics from the University of Munich.

He became professor of theoretical physics at the University of Zürich in Switzerland in 1911. The post previously had been held by Albert Einstein. Debye also taught at Utrecht, the Netherlands, and at Göttingen, Leipzig, and Berlin, all in Germany. In 1935 he became director of the Kaiser Wilhelm (later Max Planck) Institute for Physics in Berlin.

In 1940, two months before Hitler invaded the Netherlands, Debye made a visit to the United States to deliver a lecture at Cornell University, Ithaca, New York. He stayed on at Cornell until his retirement in 1950, becoming a professor of chemistry and head of the department. In 1946 he became a U.S. citizen.

In addition to the Nobel Prize, Debye received numerous other awards, including the Rumford Medal of the Royal Society and the Priestley Medal of the American Chemical Society. In 1947 he became a member of the National Academy of Sciences.

DE CANDOLLE. See Candolle, De, Family.

DE COULOMB. See Coulomb, Charles Augustin de.

DE FERMAT. See Fermat, Pierre de.

DE FOREST, LEE (1873–1961)

One of the greatest contributors to the modern communications industry was the American engineer and inventor Lee De Forest. His radio tube, or audion, formed the backbone of early radio technology. His glow lamp made possible the conversion of silent films into talkies.

De Forest was born in Council Bluffs, Iowa. Early in life he showed his talent for inventing. He was educated at Yale University and received his doctorate in 1899. After graduating he worked for a time at the Western Electric Company's telephone laboratory in Chicago.

The wireless telegraph attracted his interest, and he developed a way to speed up the transmission of signals. In 1904 his wireless telegraph system was used to transmit news about the Russo-Japanese War, the first time that news had been reported by wireless.

De Forest became interested in transmitting the human voice by wireless, and so he went to work on developing his radio tube. In 1906 he modified the electron tube by adding a third electrode, called a grid, and thereby created the triode, which became the basic element in the radio tube. Gradual... it was discovered that this device ...ld be used as a radio detector, ampli... and oscillator.

In 1907 he succeeded ... ansmitting the human voice by ... telephone. Three years later he plac... icrophones in New York City's Metr... tan Opera House and broadcast the ... of Enrico Caruso. This was the first ... broadcast of its kind. De Forest est... ed a radio station in 1916 and from ... transmitted the first radio news...

He then turned to sou... production for motion pictures. He ...ked out a process whereby the ir... larities of sound waves created irre... ities in the brightness of a lamp fila... t. The fluctuating brightness of the ... lamp was photographed along with t... motion picture and then converted ... sound. In 1923 De Forest exhibited t... world's first sound-on-film motion pict... it the Rivoli Theater in New York.

Being a highly unsucc... business-man, De Forest was cons... ly running short of funds. He was ... often involved in lawsuits. Once, ... e result of an attempt to raise funds ... e development of his audion, he wa... n arrested on a charge of using the m... o defraud. Finally, he sold his audion ... he American Telephone and Telegra... Company for a total of $390,000. He m... d to Hollywood, California, where h... ed in relative quiet for the rest of h... life.

Lee De Forest

During his lifetime De Forest patented more than 300 inventions in such fields as radiotelephony, sound motion pictures, high-speed facsimile transmission, television, and radiotherapy. He also designed and installed the first high-power radio station [illegible] the U.S. Navy. *Father of Radio* (19[illegible] is his autobiography.

DE HEVESY. [illegible] Hevesy, George de.

DE LAPLACE. [illegible] Laplace, Pierre Simon de.

DELBRÜCK, [illegible] (1906–)

One of th[illegible]bers of the three-man research te[illegible]t won the 1969 Nobel Prize in phy[illegible]y or medicine was Max Delbrück, a [illegible]lized American physicist and bi[illegible]t. His colleagues were Alfred D. H[illegible] and Salvador E. Luria, and the thre[illegible]often referred to as the Phage Grou[illegible]e Alfred Day Hershey; Salvador Ed[illegible] Luria.)

Max Delbrück

Their basic research into the nature and genetics of viruses was done primarily between 1940 and 1952. It was so basic that without it James D. Watson and Francis H. C. Crick could not have discovered the molecular structure of deoxyribonucleic acid (DNA), for which they won the Nobel Prize in 1962.

Delbrück, an opponent of biological warfare work, began his viral research at Vanderbilt University, Nashville, Tennessee. He developed a method of purifying viruses in order to study them and discovered that a single virus invades a single bacterial cell. Together with Luria he studied the interaction between viruses and the bacteria they infect. The men discovered that both the viruses and the bacteria could mutate, thereby changing both their infectious characteristics and their immunities. These findings enabled others to develop vaccines against such virus-caused diseases as mumps, polio, and German measles.

Delbrück, born in Berlin, Germany, received his doctorate in physics at the University of Göttingen in 1930. He was a Rockefeller Foundation fellow in Copenhagen, Denmark, and Zürich, Switzerland, and worked at the Kaiser Wilhelm Institute in Berlin before moving to the United States in 1937 to join the faculty of the California Institute of Technology, Pasadena, again as a Rockefeller Foundation fellow. He went to Vanderbilt University two years later as an instructor in physics but returned to the California Institute of Technology in 1947 as a professor of biology.

He was elected to the National Academy of Science in 1949, received the Kimber Genetics Award in 1965, and with Luria won the Louisa Gross Horowitz Prize shortly before receiving the Nobel award. Delbrück donated his half of the $25,000 Horowitz award to Amnesty International, an independent group working in behalf of all political prisoners.

DE LESSEPS. See Lesseps, Ferdinand de.

DEMOCRITUS (about 450 B.C.)

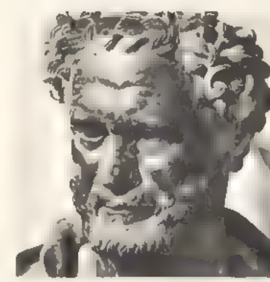
The greatest of all the ancient Greek physical philosophers is said to have been Democritus, who lived and worked in the late fifth and early fourth centuries B.C. The exact dates of his birth and death are unknown, and nothing but fragments of his writing exist today. What is known of his life and thought has been found mainly in the works of others. Because he had a cheerful view of the universe and laughed at human foibles, he is often referred to as the Laughing Philosopher.

Democritus was born either at Abdera in Thrace or at Miletus. Before settling down he apparently traveled extensively in the East and studied mathematics and physical systems in Egypt. His teacher was supposedly the Greek philosopher Leucippus, about whom also little is known. Atomism, however, was said to have originated with Leucippus; and since Democritus expanded on the ideas of Leucippus, he is regarded as one of the founders of atomic theory. Although Democritus arrived at his conclusions through intuition and introspective thought, many of his notions bear a remarkable resemblance to modern scientific theories.

According to Democritus the universe consists of Being and not-Being, or atoms and the void. In his system, atoms are the smallest, indivisible particles of matter, and the void the space in which they move. The differences between substances he attributed only to differences in the shapes of atoms. For example, he regarded water atoms as being round and smooth, and iron atoms as rough edged, which explained why water atoms loosely tumble over one another, and iron atoms cling together.

Philosophically, Democritus was one of the first mechanists. He regarded the universe as being mindless but performing according to definite and necessary laws, laws inherent in the nature of atoms. In Democritus' view the universe had its beginnings in a vibrating movement of the atoms in all directions. This resulted in collisions and a whirling motion, whereby similar atoms were united to form larger bodies and, eventually, whole worlds. Democritus also subscribed to

Democritus



At the time of Democritus, Athens was a vital center of learning; and although it is not known whether he actually visited it, it is certain that he wanted his ideas accepted there.

the notion that nothing arises out of nothingness and that nothing can be reduced to nothingness. This anticipated the modern ideas about the indestructibility of matter and the conservation of energy.

The thought of Democritus extended to almost every area of learning recognized during his time. He had theories about sensation, perception, knowledge, ethics, and theology. One of his more curious theories concerned the human body and the human soul. According to Democritus the soul is the most important part of man and pervades his whole being. Between every two body atoms is a round, smooth, and mobile soul atom.

DE MONET. See Lamarck, Chevalier de.

DESCARTES, RENÉ (1596–1650)

The greatest of the French philosophers, René Descartes, also used his analytical genius in the invention of coordinate geometry and in contributions to theoretical physics and scientific methodology.

Descartes was born at La Haye, Touraine, the third child of Joachim Descartes, a member of the provincial nobility and a parliamentary deputy. His mother, Jeanne Brochard, died soon after he was born, and he was reared by his maternal grandmother and a nurse whom he remembered with love for the rest of his life. Descartes was delicate, and the doctors predicted that he would die young. His father, for fear of tiring him with studies, wanted to postpone his education; but because the child showed a lively interest in everything around him and had a great desire to learn, his father sent him, at the age of ten, to the Jesuit college at La Flèche. His friendly nature and lively mind made him a favorite among the fathers, who allowed him to study what he wanted and to stay in bed late in the mornings because of his delicate health.

After eight years he left the college full of gratitude and respect for his teachers but with little faith in his own intellectual capacities. He therefore abandoned books for some time and turned to Parisian society life. These activities lasted only a short time, however, because almost immediately he made friends with the scholar Father Mersenne, who persuaded him to return to study and meditation. To escape from the social obligations imposed on him by his wide circle of acquaintances in Paris, he enlisted in Maurice of Nassau's army in Holland in 1618. Since he found garrison life tedious and wanted to avoid its rigors, he refused to accept any pay and eventually kept only one Spanish doubloon as a memento.

Subsequently, Descartes resumed his travels and later joined the troops of Maximilian of Bavaria. Even then he secluded himself for such intensive study that he soon succumbed to acute exhaustion, which made him subject to hallucinations. On November 10, 1619, he bivouacked with Maximilian's army at Ulm, Germany, and during the night, in a mystical vision, he had a revelation of all sciences interlocking "as a chain."

During his stay in Holland (1629–1649), René Descartes published his principal works. Although he moved around a lot, it is known that he lived in this house in Leiden in 1642.

René Descartes

This dream revelation persuaded him to devote himself heart and soul to study and meditation. After a last military campaign at Prague he abandoned the army and went on a tour of northern Europe.

His restless wanderings then took him back to Paris, France, where he was once more obliged to protect strenuously the time that he devoted to study from the intrusions of his friends and admirers. He was even forced to conceal where he lived. Nonetheless, he took part in various literary gatherings, and at the instigation chiefly of Cardinal Beroulle he was persuaded to follow what he considered the divine will by divulging his philosophy. In order to work he went to Holland, which allowed him to be readily in touch with the new ideas of French scholars and at the same time to be quiet and free from social obligations.

In Rome, Descartes had observed a parhelion, a kind of solar halo produced by a veil of clouds. This phenomenon caught his imagination and subsequently he was led to make a study of its causes and, more generally, a study of optics and physics. This resulted in three important treatises: *Dioptrique* (dioptrics, the theory of refraction), *Météores* (meteors, celestial phenomena) and *Géométrie* (analytic geometry, the application of algebra to geometry)

He wrote the three books in succession, but, before embarking on the third, he realized the need to give the whole treatment a logico-geometric ordering suggested to him by the spirit that already pervaded the earlier works but that required some justification or, better still, a separate discussion. He therefore added a brief preface, in which he expounded the method that he was following in these works and that, more generally, he considered should be followed in the writing of any scientific or philosophical work. Conceived as a simple introduction, this became Descartes' most important work: *Discourse on the Method of Properly Guiding the Reason in the Search for Truth in the Sciences.* It contains the bases of scientific reasoning: to start from undeniably true premises, to split up difficult arguments into a number of parts and treat these one by one, and to avoid omissions in the course of lengthy reasoning. His work met with some opposition, but his method was soon accepted as a great intellectual triumph.

In geometry Descartes' main achievement was the idea of applying algebra to the study of geometric problems. According to Descartes every figure traced on a plane is composed of points, and the position of every point can be de-

scribed by two numbers, or coordinates, just as the position of a point on the Earth's surface is determined by both latitude and longitude; every geometric figure can be represented by means of an algebraic equation, and geometric problems can therefore be solved algebraically; conversely, geometry can clarify the significance of algebraic formulas. Descartes' m[illegible] of interpreting formulas was to l[illegible] to the notion of mathematical functi[illegible] to the invention of infinitesimal [illegible], together with the notion of lim[illegible] evolution of which belongs to th[illegible] [illegible]ediate post-Cartesian period. The [illegible] [illegible]eries that the geometric metho[illegible] Cartesian coordinates enabled him t[illegible] [illegible]ke are numerous. He did not, howe[illegible] confine his mathematical abilities [illegible] study of geometry but also und[illegible] other studies, among them the the[illegible] numbers.

Louis XIV gr[illegible] Descartes a pension in the hope of [illegible]suading him to return to France to j[illegible] Louis' entourage. Descartes, howev[illegible] had other plans. The French ambas[illegible]or at the Swedish court, Chanut, had [illegible] to Queen Christina about the ph[illegible]her. The queen had a great passion [illegible] philosophy and wished to study it at [illegible] and from a great master of the su[illegible] whose ideas she felt she shared. I[illegible] [illegible]tember of 1649 Descartes left H[illegible] bound for Sweden.

His missio[illegible] [illegible]ask proved so burdensome that it [illegible] to his grave. Apparently, the q[illegible] administrative duties were heavy [illegible] he started to deal with affairs of st[illegible] seven o'clock in the morning, mak[illegible] Descartes give her lessons earlier [illegible] at five. He found the schedule diffic[illegible]lt, since he had never abandoned the habit of lying in bed late. After a few months he was exhausted, caught a morning chill, and died.

DE VRIES, HUGO (1848–1935)

Hugo de Vries, Dutch botanist and geneticist, opened a new epoch in the study of evolution by introducing the experimental method, as opposed to the old method of observation and inference. De Vries is best known for his theory of mutation: new species of plants or animals originate by a change in the genes of the existing species.

In the course of his research, De Vries rediscovered Gregor Mendel's theories thirty-four years after Mendel set them forth. By making Mendel's laws of inheritance known to the world of science and by supplementing them with his own mutation theory, De Vries filled in the gap in Charles Darwin's theory of evolution, which had not accounted for individual variation.

Coincidentally, De Vries was one of three investigators who independently rediscovered and confirmed Mendel's laws of heredity in the year 1900. The others were E. Tschermak von Seysenegg of Austria and K. E. Correns of Germany.

De Vries, the son of a former prime minister, was born in Haarlem, the Netherlands, and studied at Leiden and at Heidelberg and Würzburg in Germany. From 1878 to 1918 he was a professor at the University of Amsterdam. He earned an international reputation with his study of plant cells. In the 1870s the Prussian Ministry of Agriculture asked him to prepare monographs on cultivated plants. He wrote three—on clover, sugar beets, and potatoes. This experience proved useful also in his studies of genetics. De Vries began to breed plants in 1892. When he reached definite conclusions about the variations and was preparing to publish, he read the existing literature on the subject and found that Mendel had come to the same conclusions a generation earlier.

After retiring from his university post, De Vries continued his experimental work in plant culture. His best-known works are *Intracellular Pangenesis* (1889), *The Mutation Theory* (1900–1903), and *Plant Breeding* (1907).

DIELS, OTTO PAUL HERMANN (1876–1954)

The German chemist Otto Paul Hermann Diels won the 1950 Nobel Prize in chemistry for discovering the diene synthesis. He shared the prize with his assistant Kurt Alder, who also participated in the discovery that was so fundamental to modern organic chemistry. Sometimes the diene synthesis is called the Diels-Alder reaction in their honor.

A diene is an organic substance that consists of two double-bonded carbon atoms. Basically the diene synthesis involves joining two compounds to make a ring of atoms. Diels and Alder were able to use dienes to synthesize many organic substances. The diene synthesis is incredibly versatile in that the components can be changed or varied without destroying the basic unifying process. One interesting feature of the reaction is that it does not require unusual temperatures. An important application of the synthesis is found in the production of plastics. Diels and Alder published their paper on the synthesis in 1928.

Earlier in his career Diels had discovered carbon suboxide and determined its properties. He also worked in the obscure field of sterol chemistry. He devised a method for removing hydrogen atoms from the molecules of organic compounds containing a great deal of hydrogen.

Diels was born in Hamburg, Germany. In 1899 he received his doctorate in chemistry from the University of Berlin and joined its faculty as a professor of chemistry. He moved to the University of Kiel in 1916, becoming professor emeritus there in 1948.

DIESEL, RUDOLF (1858–1913)

The internal-combustion engine may, from a certain point of view, be considered as the natural development of the steam engine. The difference between them is that the thermodynamic cycle that makes a steam engine work comes about by means of forcing a heated fluid (steam) into a cylinder in which the steam undergoes expansion and in which a piston transforms the heat energy into mechanical energy. The efficiency of this type of engine is not great, but the engine has the advantage of using a low-cost fuel. In an internal-combustion engine the fluid is heated within the cylinder, and upon the fluid's expansion in the cylinder a piston similarly converts heat energy to mechanical energy. This newer process, however, requires the use of chemically stable materials that will stand high temperatures. The common automobile engine is an internal-combustion engine that requires an external source to ignite its fluid—gasoline, which is relatively expensive. The diesel engine is an internal-combustion engine that needs no ignition system for its fluid—the heavier and less expensive oils.

Rudolf Diesel had always firmly believed that one day he would become famous. As a boy he was at the top of his class, by the time he was fourteen he was already well aware of his intellectual superiority, and by the age of eighteen he had decided that one day he would make his mark in science.

His strength of character, steadfastness of purpose, and willpower were guided by his mother, Elise Strobel, a German governess with an excellent knowledge of languages who had married Theodor Diesel in 1855. Her husband had emigrated from Augsburg in Germany to Paris at the age of twenty in search of fortune. Following the family tradition, he had intended to remain an independent artisan, in a small leather business; but as he lacked the ability to keep up with the latest industrial developments, he continued to struggle in an impasse.

In 1870, during the Franco-Prussian War, the Diesels and their three children (Rudolf and his two sisters), being of German nationality, were forced to move to London. They were even worse off than before and obliged to part from their son, who was sent to live with some relatives in Augsburg.

Rudolf Diesel

Rudolf thus found himself at the age of twelve far from his family. The letters he sent his parents reveal a longing for love, great homesickness, and a firm intention to become someone, to win for himself a secure, untroubled future that his family had never known; and they show, too, that he knew that the only way for him to get where he wanted was to study. Despite his difficulties, he passed his exams at the Munich Industrial School and in 1875 achieved his wish of entering the Polytechnic.

Diesel was still a student when, in a class on heat engines, taught by the inventor Karl Linde, he developed an idea of basic importance. In view of the very low efficiency of heat engines, especially of those driven by steam, which frequently managed to transform less than 10 percent of the energy supplied to them into mechanical energy, he thought of trying to heat directly inside the cylinder the fluid that was to be expanded, thus eliminating the loss of heat that occurred during the fluid's passage from the furnace to the boiler. This idea consumed most of Diesel's attention for the next few years.

In 1879 he took a degree, amid the professors' congratulations, and became the agent for Linde's machines in Belgium and France and was soon entrusted with the opening and management of new factories.

His interests were divided between the technical problems inherent in his profession (some of which, like those relating to high pressures, were to prove useful to him later when he was studying the realization of his engine) and social questions; for Diesel, an independent by conviction, was particularly interested in the question of the welfare of the working classes. Shortly before his death he was to publish a book entitled *Solidarismus*, which was to be dubbed "the printed utopia of a lone spirit" because Diesel had no knowledge, or at best a hazy and out-of-date one, of mass psychology and seemed unaware that there had been any changes in political conditions. Thus, his social activities and generous gifts of money were to be criticized even in Marxist circles.

Diesel, who was continually in search of fresh fields in which to apply a freezing technique, took out his first patent in 1881, in France. This was for a process of manufacturing transparent ice to be used in cold drinks, replacing the usually opaque ice containing bubbles.

In 1883 he married Marte Flasche, a German schoolteacher, who bore him three children—Rudolf, Hedy, and Eugen.

Using his own savings, Diesel in 1885 began to design models for an ammoniac gas engine, which he hoped would be a small engine with an economic fuel consumption and suitable for small-scale industry. Two years later he had decided that the heating of compressed air would serve his purpose. In his theoretical engine it was the very fast compression of the air without heat loss or gain that could bring about the ignition of the fuel; the result was to be an engine with a much higher efficiency than the gasoline engine.

Early in 1892 Diesel obtained a German patent for a producer-gas engine and, to draw the financial backing he needed, set forth a description of it in a treatise entitled *The Theory and Construction of a Rational Heat Motor*.

Many greeted his work with distrust and irony, calling it "a paper machine." Others, however, such as Alfred Krupp, realized its possibilities; and an agreement was signed with Krupp and the Maschinenfabrik of Augsburg giving the German factories the sole rights of manufacture of the engine in Germany in exchange for the funds needed for its construction.

Twenty years of feverish activity began. Driven by the thirst for power that had consumed him since he was a child, Diesel would not allow himself a moment's pause or relaxation. His first concern was for the construction of the engine; but even when that had begun, there was still the problem of finding the most suitable fuel for it: coal-tar naphtha, gasoline, oil, and finally gasoline again, this time directly injected into the engine without electrical ignition.

When, on February 17, 1894, his engine—his "black sweetheart"—at last worked, Diesel broke down and threw himself into his wife's arms in tears. Enthusiastic acclaim awaited h[illegible]m, but bitter disputes dragged on f[illegible] ears.

In 1895 the Diesels went [illegible]ck to Munich, where, at the turn o[illegible] century, they had a luxurious home [illegible]ilt and began to lead the life of eas[illegible]ical of the local upper middle class. [illegible] was more than rich.

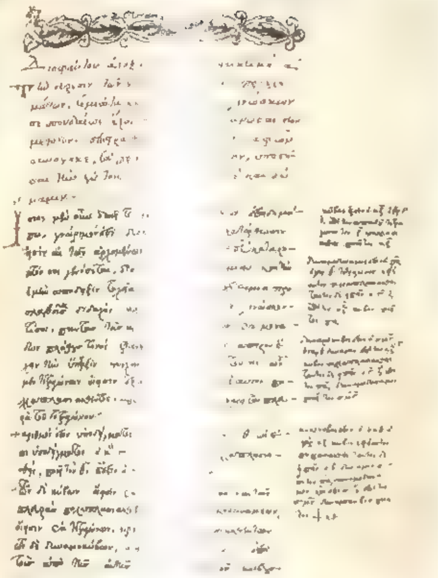
His forced inactivity a[illegible]he incompetence of some of the [illegible]ers of his factories hastened the mo[illegible] of disaster that Diesel sought despe[illegible] to avoid, taking refuge behind a [illegible] of prosperity and risking finan[illegible]eculations that grew more and mo[illegible] and unsuccessful. His pride, w[illegible] prevented him from admitting his [illegible]takes and seeking help, was to be h[illegible]n.

Sadly, his unremitting [illegible]ivity and, above all, the ups and d[illegible] of all his hopes and disappointment[illegible]d their effect on his already frail n[illegible]us system, and at the peak of his care[illegible] Diesel twice had to enter mental hom[illegible] 1898 and 1901).

On September 29, 191[illegible] few days after the publication of [illegible]ook *The Genesis of Diesel Motors* [illegible] embarked in the evening on the ste[illegible] *Dresden* bound for Harwich, E[illegible]d, from where he was to go to Ip[illegible] to see a new factory and then on [illegible] meeting in London. He was never [illegible]ive, however; the next morning h[illegible]d disappeared, presumably drown[illegible] It is believed that he preferred de[illegible] to having to face a reality that c[illegible]icted so strongly with his aspiration[illegible]

DIOPHANTUS (3rd century A[illegible])

"Here lie the mortal remains of Diophantus, who spent a sixth of his life in childhood, entered adolescence after another twelfth, and married after another seventh. After five years of childless marriage a son was born to him, who died when he had barely reached half the age that his father was to reach. The father survived his unfortunate son by four years." If this information were reliable, Diophantus' career could be easily reconstructed on the basis of a simple equation. He would have passed out of childhood at fourteen, reached manhood at twenty-one, married at thirty-three, become a father at thirty-eight, and lost his son when he was eighty, dying himself at eighty-four. Unfortunately, however, this information is quite unsupported by reliable evidence; it merely appears in a book of mathematical exercises and problems, the *Greek Anthology*,



Diophantus is best known for the *Arithmetica*.

compiled by a certain Metrodorus between the 5th and 6th centuries A.D. This text has no historical pretensions; moreover, it is unlikely that the dates and events of Diophantus' career could be dovetailed with such precision. The dates of his birth and death are unknown, nor is it even known exactly when his works appeared.

While his mathematical brilliance was typically Greek and followed the tradition of such predecessors as Thales, Archimedes and Pythagoras, Diophantus tackled more ambitious problems than his predecessors and began studying the possibility of using whole numbers to solve the equations in which the terms of the problem were formulated. This led him to study that branch of mathematics in which Leonhard Euler and Pierre de Fermat were to excel centuries later.

Diophantus can be said to have anticipated algebra, especially if one considers that the latter was not spontaneously conceived as one complete item. He therefore forms a link between the Greek and Arab mathematicians.

Toward the middle of the sixteenth century the incomplete works of a Greek mathematician were discovered in the Vatican Library; they were the first six books of the *Arithmetica* and a treatise, *Polygonal Numbers*, by a certain Diophantus of Alexandria, annotated by a fourteenth-century monk, Planudes Maximus.

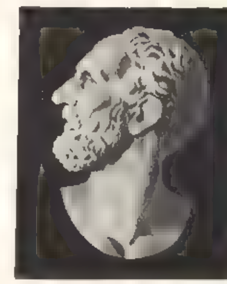
This work, circulating in France in a translated edition, attracted the attention of René Descartes and Fermat, who took a keen interest in it, both because of the value of the work and because of their desire to correct the various errors introduced by the translator, who was a mediocre mathematician. The appellation *Diophantine analysis* was then given to indeterminate analysis precisely because most of the problems proposed by Diophantus lead to indeterminate equations.

Typical indeterminate equations are those in which there are sufficient data for the writing of only one equation, while there are two unknown quantities in the problem, the presence of two unknowns requiring two equations. The result is that the solution is not unique and a formula is arrived at that makes it possible to determine the relation between the two unknowns but not their individual values. If, however, the data of the problem are whole numbers, it is possible to establish what whole solutions the problem may use. Then it is no longer an indeterminate case because there are only a few pairs of values that satisfy that formula. Diophantus adopted only rational solutions; this afforded him a wide range of solutions without any need to get involved in theory of numbers, as Euler and Fermat were forced to do later. It should be remembered that Diophantus would not have been able to establish the importance of studying the theory of whole numbers even if he could have concluded such importance from his problems. He was interested in the problems themselves and wished to solve them in the most general way possible. The mathematicians of the eighteenth century, on the other hand, were interested in the analysis of numbers, and problems were merely a pretext for studying their properties.

Even if all mathematicians are not agreed in recognizing Diophantus as the inventor of algebra, he must, nevertheless, be numbered among the precursors of this method of calculation. Taking Pythagoras' theorem alone, Diophantus made an important advance compared with his predecessors. The theorem can be expressed in words, but it can also be stated by means of a formula; and once letters of the alphabet have been given to the sides of the triangle, the statement of the theorem is simplified. None of this had been done in Pythagoras' day. Diophantus, on the other hand, began introducing symbols to denote certain mathematical operations, which had until then been indicated by words, and substituted other symbols for the geometrical quantities with which he was working. For all the unknown quantities, however, he adopted a single symbol, and this involved him in enormous difficulties whenever he had to work with two unknowns in which one was expressed as a function of the other.

His was an embryonic form of algebra, it is true, but nonetheless it was an enormous advance on earlier mathematics. In a sense, a natural evolution had taken place. The first Greek mathematicians had discussed only a few problems and

Diophantus



on these had built almost philosophical constructions, in the manner of Pythagoras. The applications of such problems did not apparently interest these mathematician-philosophers except for the limited number needed to reveal the validity of their methods. In modern mathematics, on the other hand, the situation is almost the reverse. All the mathematicians of the eighteenth and nineteenth centuries produced monumental works containing the solutions of problems; in other words, the applications of their theories. Diophantus was the first Greek mathematician who came down from the ivory tower of philosophy to treat a host of problems.

It was this approach that led to the invention of the algebraic method, even if it was only partially developed. The treatment of so many problems, and, above all, problems involving numerical solutions, inevitably leads to a monotony of language that, in turn, leads naturally to expression by means of algebraic symbols.

The great variety and the originality of the problems treated by Diophantus have given rise to the opinion that those works attributed to him were assembled under his name merely for convenient presentation. The ingenious invention of algebraic symbolism, however, is too original to be attributed to a school or to a group of problem collectors and can be ascribed only to a single personality. Even if the rudiments of Diophantine algebra are modest, their influence on the Arab world, which developed this method of calculation, was enormous.

The six books that have survived are so brilliant and fascinating that one regrets the loss of the other seven, which have been the subject of much fruitless discussion and conjecture. It has even been suggested that far from being lost, they were condensed by a copyist to form those that have survived, with the possible elimination of a few minor problems. The author dedicated his work to a certain Dionysius, a highly esteemed and influential person, who has been identified with St. Dionysius, the bishop of Paris. This hypothesis is particularly interesting because there is hardly any historical record of Diophantus. Even the period in which he lived is now the subject of controversy because it has remained unknown for so long that it is difficult to place it with any certainty within well-defined limits.

Although Diophantus lacked the power and originality of Archimedes and the authority of Euclid, his importance is beyond question. It lies, above all, in the inspiration that his ideas provided, many centuries later, for the brilliant work of both Fermat and Euler.

DIRAC, PAUL ADRIEN MAURICE
(1902–)

The first investigations into the world of antimatter were prompted by the British mathematician and physicist Paul Adrien Dirac. He theoretically proposed the existence of the positron and reasoned that the combination of an electron and a positron would result in a chargeless photon. For his work in this area of quantum mechanics Dirac shared the 1933 Nobel Prize in physics with Erwin Schrödinger. (*See* Erwin Schrödinger.)

In 1925 the hypothesis that electrons spin on their own axes was first advanced. The spinning-electron hypothesis then had to be theoretically explained as a fundamental of quantum mechanics. Dirac undertook the task and worked out mathematical equations to explain the spin of electrons. His work in this area, however, led him to believe that electrons could have opposite energy states, one positive and one negative. Dirac reasoned that each electron had an opposite particle identical in every way but for a reverse electric charge. The proton was obviously not the answer, since a proton is 1,836 times larger than an electron. Dirac's equations also suggested that for each proton there was an identical particle with an opposite charge. Dirac was proved correct when two years later Carl David Anderson discovered the antielectron, or positron. Subsequently the antiproton and other antiparticles were discovered.

Dirac was born at Bristol and studied electrical engineering at the university there. After graduating he pursued mathematics, receiving his doctorate from Cambridge University in 1926.

Paul Dirac

During the period 1929–1931 he was a guest lecturer in the United States at the University of Wisconsin, the University of Michigan, and Princeton University. In 1932 he was appointed Lucasian Professor of Mathematics at Cambridge, a post once held by Isaac Newton. Eight years later he became a professor at the Dublin Institute for Advanced Studies, and from 1947 to 1948 and again from 1958 to 1959 he was a member of the Institute for Advanced Study at Princeton, New Jersey. He won the Royal Medal of the Royal Society in 1939 and the Copley Medal in 1952. In 1949 he was made a foreign associate of the U.S. National Academy of Sciences.

DOBZHANSKY, THEODOSIUS
(1900–)

The Russian-American biologist Theodosius Dobzhansky increased substantially the understanding of mechanisms of heredity and variation. He is known especially for his research in population genetics, which deals with the origin of species and other natural categories in order to analyze the processes of evolution.

Dobzhansky observed the operation of natural selection in populations of *Drosophila*, a genus of flies commonly known as vinegar, or pomace, flies and misleadingly known as fruit flies, which belong to a different family. He found that genetic mechanisms cause *Drosophila* to form subspecies that adapt to differing environments and cannot interbreed. There are 1,000 or more species of *Drosophila*. Some lend themselves particularly to experiments on heredity and evolution because their life cycles are less than two weeks long. In that time a pair can produce hundreds or even thousands of offspring. Moreover, the giant chromosomes in the cells of the salivary glands of mature larvas are easily accessible for study.

Dobzhansky was born in Nemirov, Russia, and graduated in 1921 from the University of Kiev, where he majored in zoology. He lectured on genetics at the Polytechnical Institute at Kiev until 1924 and at the University of Leningrad from 1924 to 1927. During the next two years he was a fellow of the International Education Board, working first at Columbia University, New York City, and later at the California Institute of Technology, Pasadena, with T. H. Morgan, pioneer researcher on the genetics of *Drosophila*. He became assistant professor of genetics at the latter school in 1930 and professor in 1936. Four years later he returned to Columbia as professor, serving there until 1962, when he joined the Rockefeller Institute. He was a visiting professor in Brazil, Chile, and Australia, and conducted research in many countries.

Theodosius Dobzhansky

For his work in heredity and genetics Dobzhansky was widely honored by universities and scholarly societies. In 1958 he received the Kimber Genetics Award of the National Academy of Sciences. This was followed in 1964 by the National Medal of Science. He became a U.S. citizen in 1937.

Books by Dobzhansky include *Evolution, Genetics, and Man* (1955), *The Biological Basis of Human Freedom* (1956), *Mankind Evolving* (1963), *Heredity and the Nature of Man* (1964), and *Biology of Ultimate Concern* (1967).

DOISY, EDWARD ADELBERT
(1893–)

The 1943 Nobel Prize in physiology or medicine was shared by the U.S. bio-

chemist Edward A. Doisy and the Danish biochemist Carl P. H. Dam for their work on vitamin K, a substance necessary for blood coagulation. Dam identified it, and Doisy headed a research group that isolated it. (*See* Carl Peter Henrik Dam.)

Earlier in his career Doisy became the first person to isolate sex hormones. In 1929 he and his associates isolated estrone, a crystalline female sex hormone. Later they isolated two related hormones.

It was in 1936 that Doisy turned his attention to Dam's discovery—announced two years earlier—of the food factor vitamin K. In their attempts to find out its chemical makeup, Doisy and his colleagues successfully isolated two compounds: vitamin K_1 from a plant source, and vitamin K_2 from cultures of microorganisms. Doisy worked out the chemistry of the compounds and synthesized vitamin K_1.

Doisy was born in Hume, Illinois, and received his bachelor's degree in 1914 and his master's in 1916 from the University of Illinois. He received his doctorate from Harvard University in 1920, having interrupted his studies to serve two years in World War I. From 1919 to 1923 he taught at Washington University School of Medicine in St. Louis, Missouri. He was appointed to the chair of biochemistry at St. Louis University School of Medicine in 1923 and was named distinguished service professor in 1951.

Doisy's later work included important research on the metabolism of hormones and bile acids. He was elected to the National Academy of Sciences in 1938.

DOMAGK, GERHARD (1895–1964)

The German pathologist Gerhard Domagk won the 1939 Nobel Prize in physiology or medicine for his discovery of the antibacterial effects of prontosil, a synthetic red dye. The power of prontosil was brought home dramatically when Domagk used it to cure his own daughter of a grave streptococcal infection.

Domagk was born in Lagow, Brandenburg, Germany. His studies at the University of Kiel were interrupted when he volunteered for service in World War I. He served throughout the war and finished his medical studies in 1921.

While working at the Pathological Institute at Münster, where he later became professor of general pathology and pathological anatomy, Domagk accepted a position in 1927 with the I. G. Farbenindustrie. He was appointed director of the dye firm's laboratory for experimental pathology and bacteriology at Wuppertal.

In the course of his investigations of the therapeutic possibilities of new compounds synthesized by chemists at the company, Domagk was impressed by one of the dyes that contained a sulfonamide group. It had a marked effect on bacterial infections in experimental mice, and it was to prove highly successful in clinical practice. Domagk's first report on prontosil in 1932 opened the age of chemotherapy in medicine. Later the pharmacologist Daniel Bovet discovered that sufanilamide is the effective agent in prontosil.

In October 1939 the Nobel committee received Domagk's letter acknowledging his acceptance of the award, but in a letter a month later he declined it. Eventually, it was revealed that Domagk had signed the letter under duress while held by the Nazi secret police. Adolf Hitler had forbidden Germans to accept any Nobel Prize, because he was outraged in 1935 when the Nobel Peace Prize went to one of his political prisoners, Carl von Ossietzky, an active pacifist whom he had arrested in 1933 and confined to a concentration camp. In 1947 Domagk visited Stockholm, delivered his Nobel lecture, and received the gold medal and diploma. The prize money, however, had by then reverted to the Nobel Foundation.

Besides his research into the treatment of acute infections, Domagk did considerable work on tuberculosis and cancer. He was made a foreign member of the Royal Society of London in 1959.

DRAPER, HENRY (1837–1882)

The U.S. physician, chemist, and astronomer Henry Draper obtained the first stellar spectrogram in 1872 and the first photograph of a nebula, Orion, eight years later. In his spectroscopic work he produced the first ruled metal gratings, proof of the existence of oxygen in the sun, photographs of Venus in 1874, and a catalog of spectroscopic types.

Draper was born in Prince Edward County, Vermont, the son of John William Draper, a professor of both chemistry and medicine. The father experimented with photochemistry, took the first portrait by light, and in 1840 obtained the first photograph of the moon. Following in his father's footsteps, Henry pursued a medical education, later becoming a professor of natural science and chemistry. In 1859 he joined the staff of Bellevue Hospital in New York City and in 1866 was made dean of the University of the City of New York. His many honors included membership in the National Academy of Science, the American Philosophical Society, and the American Academy of Arts and Sciences.

DRIESCH, HANS ADOLF EDUARD (1867–1941)

Hans Adolf Eduard Driesch, one of the earliest experimental embryologists, was a German biologist and philosopher. He was a strong advocate of vitalism, the theory that life cannot be explained mechanically through physical or chemical structures.

The preformation theory of embryology holds that the egg contains all organs preformed, though invisible. The theory of epigenesis denies any such organization of the egg and contends that organs originate as a result of certain interactions. Driesch experimented with the two-celled embryo of the sea urchin; after he separated the two cells, each gave rise to a new larva, thus lending support to the theory of epigenesis.

Driesch was born in Bad Kreuznach, Rhenish Prussia. He was educated at the Johanneum School in Hamburg and at Freiburg and Munich before graduating from Jena in 1889.

From 1891 to 1900 he worked in a zoological station in Naples, Italy. It was there that he performed his embryology experiments with sea urchins. After leaving Naples, he settled in Heidelberg, becoming a professor of philosophy there in 1911. Appointments to professorships at Cologne and Leipzig followed in 1920 and 1921, respectively. In 1911 he was honored with a foreign membership in the Linnean Society of London.

DUMONT, ALLEN BALCOM (1901–1965)

The U.S. engineer Allen B. Dumont was a pioneer in the practical development of television, holding more than thirty patents on TV and cathode-ray tubes. Before his discoveries in the 1930s, cathode-ray tubes were imported from Germany at high cost and lasted only about twenty-five hours. Dumont's tubes were simpler, cheaper, and longer lasting.

Dumont was born in Brooklyn, New York. Upon receiving a bachelor's degree in electrical engineering from Rensselaer Polytechnic Institute, Troy, New York, in 1924, he worked as an engineer for the Westinghouse Lamp Company in Bloomfield, New Jersey, until 1928. Then, for the next three years, he was chief engineer for the De Forest Radio Company, Passaic, New Jersey. While there he participated in the production of the first TV transmitter to make a simultaneous broadcast of sight and sound.

In 1931 Dumont formed his own company, Allen B. Dumont Labs, Inc., serving as president until 1956 and then as chairman. Although he had little working capital and the market for television was virtually nonexistent, the company began to flourish as a result of his discoveries. In addition to producing television components—the first home television receiver was marketed by Dumont's firm—the company manufactured cathode-ray oscillographs, used by scientists to measure the performance of electric circuits. The oscillographs provided a steady source of income for the company for some time, but in the late 1950s business faltered and the company was absorbed by larger corporations. His other business ventures included ownership of a number of television broadcasting stations, as well as operation of the Dumont TV network.

Dumont received the American Television Society Award in 1943 and the Marconi Medal of Achievement in 1945. Honorary degrees were awarded to him by his alma mater, Rensselaer, and by the Brooklyn Polytechnic Institute.

DU VIGNEAUD. See Vigneaud, Vincent du.

EADS, JAMES BUCHANAN
(1820–1887)

For meeting and overcoming challenges of great dimension, the U.S. hydraulic engineer James Buchanan Eads became the first American to win the Albert Medal of the British Royal Society of Arts. He is especially remembered for the feat of opening and fixing a ship channel at the mouth of the Mississippi.

Eads was born in Lawrenceburg, Indiana, and worked at a variety of jobs after leaving school at the age of thirteen. After noting the great number of wrecks in the Mississippi River while working as a purser on a steamboat, he devised a diving bell and became a salvage engineer at the age of twenty-two. This endeavor made him financially able to establish at St. Louis, Missouri, the first glassworks west of the Ohio River. The enterprise was short lived, however, and Eads resumed his lucrative salvage work on the Mississippi. When the Civil War erupted in 1861, Eads advised President Lincoln that a fleet of steam-propelled, armor-plated gunboats on the Mississippi would be advantageous to the Union. Eads contracted to build seven 600-ton gunboats, without their guns, in a period of sixty-five days. He delivered the first in forty-five days and the others soon after. Altogether Eads built or converted a total of twenty-five such boats.


James Eads

After the war Eads contracted to build a bridge across the Mississippi at St. Louis. Many engineers were dismayed by the specifications, which called for a 520-foot center span with a 50-foot clearance; but Ead's familiarity with the currents and riverbed enabled him to fulfill the conditions, and the bridge was completed in 1874.

In the following year Eads was commissioned to deepen and fix a ship channel at the mouth of the Mississippi. He used a system of jetties that redirected and accelerated the current so that the river scoured its own channel and deposited its silt at sea.

ECCLES, SIR JOHN CAREW
(1903–   )

The Australian physiologist Sir John Carew Eccles shared the 1963 Nobel Prize in physiology or medicine with two British biophysicists for enlarging upon their research into the nature of nerve impulses. His co-winners were A. L. Hodgkin and A. F. Huxley. In their studies of the electrochemical basis of the excitatory process in portions of the nerve cell membrane, Hodgkin and Huxley showed how the nerve impulse is generated by the movements of ions, such as sodium and potassium, across the membrane. (*See* Alan Lloyd Hodgkin; Huxley Family.)

In 1952 Eccles and his colleagues at the Australian National University, Canberra, were able to view synaptic action —what happens at the zones of close contact between nerve cells during the transmission of the nerve impulse—by inserting into nerve cells extremely fine glass tubes filled with conducting salt solution. From the beginning Eccles was concerned with the detailed mechanism of nervous activities; and later he concentrated on excitation and inhibition in the central nervous system, one of his outstanding achievements being the first recording of electrical responses.

Eccles was born in Melbourne, Australia. After his graduation from Melbourne University, he went [illegible] a Rhodes Scholarship to Magdalen Co[illegible]ge, Oxford. Two years later, in 1927, [illegible] won first honors in physiology. For [illegible] next ten years he conducted ph[illegible]gical research and taught at [illegible]'s Exeter and Magdalen colleges, [illegible]eupon he returned to Australia as [illegible]tor of the Kanematsu Memorial I[illegible]te of Pathology at Sydney. In 1[illegible] he became professor of physiology a[illegible] University of Otago, Dunedin, New Z[illegible]nd, and in 1951 professor of physiol[illegible] the Australian National Univers[illegible]

In 1941 Eccles was ele[illegible] a fellow of the Royal Society of Lond[illegible] He served as president of the Austr[illegible] Academy of Science from 1957 to [illegible]. In 1958 he was knighted.

EDDINGTON, SIR ARTHU[illegible]ANLEY
(1882–1944)

The English astronome[illegible] Arthur Eddington—who turned to t[illegible]udy of astrophysics at the time o[illegible] greatest conquests in the field of [illegible]ar physics and the theory of rel[illegible]ty—is best known for his studies of st[illegible] motion.

The theory of relativity [illegible] arisen as the result of certain expe[illegible]ts that it had served to clarify and [illegible]in in full, but for many years it wa[illegible]ossible to perform experiments that [illegible]ld confirm the validity of Albert Ein[illegible]'s theory beyond any doubt.

Eddington's verifications [illegible]he theory were quite sensational. Tho[illegible]ghly convinced by the close relationship between the theory of relativity and the experimental facts obtainable from astrophysics, Eddington threw himself wholeheartedly into the study of cosmology and built up most of the theories on this subject that exist today.

Eddington was born to Quaker parents at Kendal, Westmorland, in the England of Victoria's reign. At the age of two he lost his father, the headmaster of the local school, who died of typhoid. Although the family was left in poverty, his mother managed to provide him with a good education, sending him first to Owens College, Manchester, and then to Trinity College, Cambridge.

Eddington's career began in 1906, when he became chief assistant at Greenwich Observatory, where he was concerned with spherical astronomy, meridian observations, and stellar catalogs.

The time, however, was ripe for an interpretation of the whole body of ob-

servation material in Eddington's possession. It was known that the stars move —the very measurements of their positions showed this—and that there are movements of [illegible]rs in the great stellar systems, such [illegible] that of the Galaxy; hence, the sa[illegible] laws as those applied to the molec[illegible]f a gas could also be applied, wit[illegible]ssary adjustments, to the study of [illegible] movements.

In 1904 th[illegible]y had been put forth that the sta[illegible]he Milky Way move chiefly in tw[illegible]ms and not haphazardly in all [illegible]ions. Eddington, who was a master [illegible]thematical technique, of supreme [illegible]tance in solving such problems, p[illegible] the validity of the theory by te[illegible]; he used the analysis of the frequ[illegible] of stellar movements and drew up [illegible]s of diagrams relating to this move[illegible] which were to bear his name.

In 1913 h[illegible]me Plumian Professor of Astronom[illegible]d Experimental Philosophy at Cam[illegible]ge, and a year later he was appoint[illegible]rector of the university observatory. [illegible]his time he published his first wo[illegible] the problem of the movement a[illegible]istribution of the stars and stellar [illegible]s and thereby earned the name Fa[illegible]f Stellar Dynamics.

In 1906 [illegible]rman astronomer had calculated th[illegible] energy flow produced inside a sta[illegible]hes the surface of the star either [illegible]eans of the convective movements [illegible]e stellar matter or by means of r[illegible]tion. According to his theory, stell[illegible]s moves like the water in a boiler, [illegible] the center of the star, where ener[illegible] produced, up to its surface; here th[illegible]matter radiates its thermal energy in th[illegible] form of electromagnetic radiation, which then returns, after cooling, to the center of the star. Another portion of the energy reaches the surface of the star by being radiated by the star's innermost atoms, then absorbed and reemitted by the next ones, and so on from atom to atom until it reaches the surface of the star. According to this theory the portion of the energy that is carried by radiation is greater than that carried by convection.

From about 1916 onward, Eddington studied in great detail this transport of energy, which eventually enabled him to confirm the theory. Having established that the energy given off by the stars in the form of light and heat is transmitted by radiation, he concluded that the interior of the stars is gaseous and deduced from this the fundamental relationship between the masses and luminosities of the stars. Because of this relationship, once the absolute luminosity of a star is known, its mass can also be ascertained with a considerable degree of accuracy, and vice versa. For astrophysicists this relationship is of basic importance. These studies also made possible the calculation of the very high temperatures that exist within the stars, of the order of tens of millions of degrees. Calculations indicate, for example, that the center of the sun has a temperature of about 20 million degrees centigrade.

In the meantime the brief but explosive announcement of a humble German clerk—Albert Einstein—who had been looking into certain problems connected with the electrodynamics of moving bodies had laid the foundations not only of a new theory—that of relativity—but also of a new epoch in science.

Eddington devoted the rest of his life—as mathematician, astronomer, and writer—to the study of the relationships between the theory of relativity and astrophysics. His *Mathematical Theory of Relativity*, a highly scientific and rigorous treatise, was flanked by a popular work, *Space, Time, and Gravitation.*

In pursuance of his astronomical studies Eddington insisted, despite World War I, on organizing two expeditions, one to the Gulf of Guinea and the other to Brazil, with the object of photographing the eclipse of the sun in 1919. His intent was to photograph the position of certain stars during the eclipse and thus help prove the theory of relativity.

This experiment had to show a shift in the position of the stars of just one second, which in photographic terms amounts to a few thousandths of a millimeter. Although somewhat hampered by weather conditions, it revealed the effect Einstein had predicted. For the first time a physical theory of great importance had been proved by astronomical observation.

Sir Arthur Eddington

The success of this important experiment induced Eddington to move into the field of cosmology. For example, he considered Einstein's cosmic constants the basis of those constants of nature that, as he considered them pure numbers, he hoped to calculate mathematically without having to resort to observation. This part of his research work, however, although the most fascinating, was not the most important, nor was it the most complete and conclusive.

Those few who had the chance to know Eddington loved and admired him for his simplicity. He was reserved, though not unsociable, slow and hesitant when he had to speak in public but with few equals regarding imagination, clarity, and incisiveness. There can be no questioning his intellectual magnitude, his value as a researcher, and his importance as a stimulator of the thought and research activities of those who followed after him.

EDISON, THOMAS ALVA (1847–1931)

One autumn day in 1877 John Krusei—the incorruptible John, as Edison called his superior—stared in amazement at a sketch his young employee showed him. The strange-looking mechanism, seemingly simple in construction, consisted of a metal point attached to a sort of funnel, a parchment diaphragm, a steel cylinder, and a hand crank. The department head was skeptical and bet the inventor a box of cigars that the mechanism would never work. A completed machine was soon set up; Edison wrapped a piece of tinfoil around the metal cylinder and, while this was going around, sang an old nursery rhyme, "Mary had a little lamb," into the funnel. The stupefaction of those present can be imagined when, after a little maneuvering of the machine, Edison's voice came out repeating, "Mary had a little lamb." He'd won the cigars.

This was only one of the episodes of Edison's career as an inventor—and perhaps not even the most significant one. The importance of his work can be summed up by saying that, alone, he occupied a place in the history of the technological development of the United States and of the whole world that is now filled by several highly experienced research laboratories. His activities ranged from chemistry to optics, from

acoustics to electricity. By the end of his life he had filed more than a thousand patents; while trying to decide on the final structure of a mechanism like the storage cell, he carried out at least 50,000 different experiments.

Edison's extraordinary inventive capacity is apparent from the fact that when he presented his design for the phonograph, he had not carried out a single preliminary experiment, and once it had been built and he had seen it working, he himself was amazed. The idea for it first came to him while he was experimenting with a recording machine for telegraphic communications: he had realized then that it would be possible to record the human voice.

Strangely enough, after the initial enthusiasm and polemics (some people suspected the presence of a ventriloquist in these experiments), the phonograph was put aside for ten years, after which Edison started to study the machine again and made some important modifications on it. In his improved model the tinfoil was replaced by wax and the hand crank was replaced by a motor. Subsequently, the cylinder was replaced by a disc, which is the form still used today, and the metal point was replaced by a diamond.

Among Edison's innumerable inventions, the talking machine was his favorite and the one most popular with the public. It earned him the name Wizard of Menlo Park.

Edison was born in Milan, Ohio. Later his family moved to Port Huron, Michigan, where he went only sporadically and unprofitably to school. On the other hand, he learned much from his mother, for whose teaching he always remained grateful. He showed an early interest in mechanics and had a wide-ranging curiosity and a precocious desire to be independent. At the age of twelve he started to grow fruit and vegetables in his father's garden and then went around selling his produce. In this way he managed to help his family and to acquire the money to buy the books, instruments, and chemicals that he particularly wanted.

To expand his small business he decided to get supplies in Detroit; and although this was not far, it meant spending a considerable time on the train. In order not to waste the time involved, he conducted experiments in a baggage car and sold newspapers. The newspaper enterprise proved so successful that he resolved to found and print his own paper, the *Weekly Herald*, for which he was editor, reporter, printer, and newsboy. He did all this with makeshift equipment in a quiet corner of the baggage car. Unfortunately, among the materials for his experiments was a bottle of phosphorus, which happened to break. The car caught fire, and the guard chased him out of what had become a convenient laboratory. Edison was fifteen years old at the time.

Then occurred an event that had a great bearing on his activities during the succeeding years. It so happened that he saved the life of a child of the stationmaster at Mount Clemens, Michigan; the father, out of gratitude, showed him the workings of telegraphy. Samuel Morse's recent invention was attracting great interest, particularly among the younger generation. Edison also turned his mind to it and before long not only became an expert operator but also found various ways of perfecting the instrument.

In 1869 Edison moved to New York City and was engaged by the Gold and Stock Telegraph Company. While there he invented an improved version of the stock ticker. He had previously invented and patented an electric vote recorder, but the machine had failed to interest anyone. Now, however, he managed to sell the stock ticker for $40,000. After this first economic success he decided that he was ready to work independently.

He therefore used the money, which for those days was considerable, to build what would now be called a research laboratory, but which had nothing in common with a modern establishment of this kind; Edison's laboratory looked more like a workshop. There, between 1870 and 1875, he continued his research on telegraphy, which led, among other things, to his invention of the duplex and quadruplex systems, which transmitted two and four messages, respectively, over the same telegraph line.

By 1876 his interests were so wide ranging that he decided to move to larger, quieter premises at Menlo Park, New Jersey, where he built the first example of a large-scale research center. There, in the same year, he experimented with an improved form of the telephone; and in the following year he patented the phonograph. The telephone had only recently been invented, and Edison modified it by the addition of the carbon microphone, which allowed the voice to be perfectly transformed into electric current. From then on, conversations became more intelligible, and the telephone assumed practical importance.

From that moment Edison's activities

Thomas Edison

evolved in a completely new direction. In his youth he had studied science and had only sporadically taken advantage of his capacity for invention, or rather, for turning the principles of his various scientific experiments to practical ends. Later, however, he patented and sold his ideas, which he developed in a commercially viable form. Now he decided that the best policy was not to sell ideas, but, if possible, to exploit them industrially. His laboratories therefore put his ideas into practice and began active production of his new inventions.

The discovery of electricity had suggested the possibility of adopting the voltaic arc to produce the light necessary for illumination. This was the problem that Edison tackled in 1878. Emitting only a feeble light, a gas flame would be the best for heating a body to incandescence, which would then give off an intense light. The drawbacks were the low heat level of the flame and the often imperfectly white light of the bodies to be heated. Fortunately, there were certain substances that, even at a temperature of less than about 1,300° F, emitted a very white light—oxides of certain elements that were smeared on a metal mesh surrounding the flame. Edison wondered how he could obtain the same light by means of electric energy. He thought of replacing the mesh with a carbon filament, which, being a good conductor, grew hot as an electric current passed through it. He had to overcome enormous difficulties to find the right type of carbon and finally chose a filament produced by carbonizing a cotton thread. This filament had to be placed in a vacuum. A glass bulb was therefore constructed in which a vacuum was created before the filament was positioned within it. This was how light bulbs were invented. Edison realized, however, that there was still much to be done before they could be generally adopted as a substitute for the old gas lighting.

His first step was to present his invention to the public. The scientists maintained that it would be impossible to produce an electric lamp built on Edison's principle, while the gas company shareholders, who were not so convinced

of this impossibility, tried to pass him off as an ignorant visionary. They had reckoned without Edison's tenacity, however. He tried 1,600 different methods and substances before finding the right composition for the filament of the bulb. Subsequently, his choice was improved still further; after a few years the carbon filament was produced from bamboo fiber and later from tungsten.

The first lamp was completed on October 21, 1879, and burned for forty hours. Edison then worked on developing every detail of the new lighting technique. He invented not only the method for screwing in the lamp (which is still called the Edison connection) but also new switches suitable for domestic electrical purposes. Moreover, generators had to be built to meet the need for reliable sources of electricity. On December 31, 1880, a public demonstration of the electric lamp and the first power plant was given at Menlo Park. Soon power plants were inaugurated in London, England, and New York City. He founded the Edison Electric Light Company in order to launch his invention without any risk of inferior production.

In the course of his studies on lamp prototypes, he observed that when a metal electrode was introduced into a vacuum-tight lamp, it received a negative charge when the lamp was lit but no charge when its potential was negative with respect to the lighted filament. In other words, he discovered a flow of electricity from the filament to the electrode that had been placed in the bulb. This phenomenon was named the Edison effect and, in fact, consists of the emission of electrons by the heated filament. In effect, Edison had unwittingly constructed the first diode (radio tube).

Between 1880 and 1882 Edison carried out a series of experiments on electric traction; and after building the first experimental electric railway line, he promoted the founding of the Electric Railway Company.

In 1887 another idea suddenly occurred to the inventor, that of moving pictures. Four years later he applied for a patent for the Kinetoscope, an instrument that projected pictures of the motion of a body, taken in rapid succession, onto a screen, at a rate of forty-eight pictures a second, thus reproducing the effect of movement in a lifelike way. It is considered to be the forerunner of the modern cinema. He had no great faith in his invention, however, and the addition of sound was the only subsequent improvement that he made on it. The introduction of sound did not convince him either, but it was destined for great success.

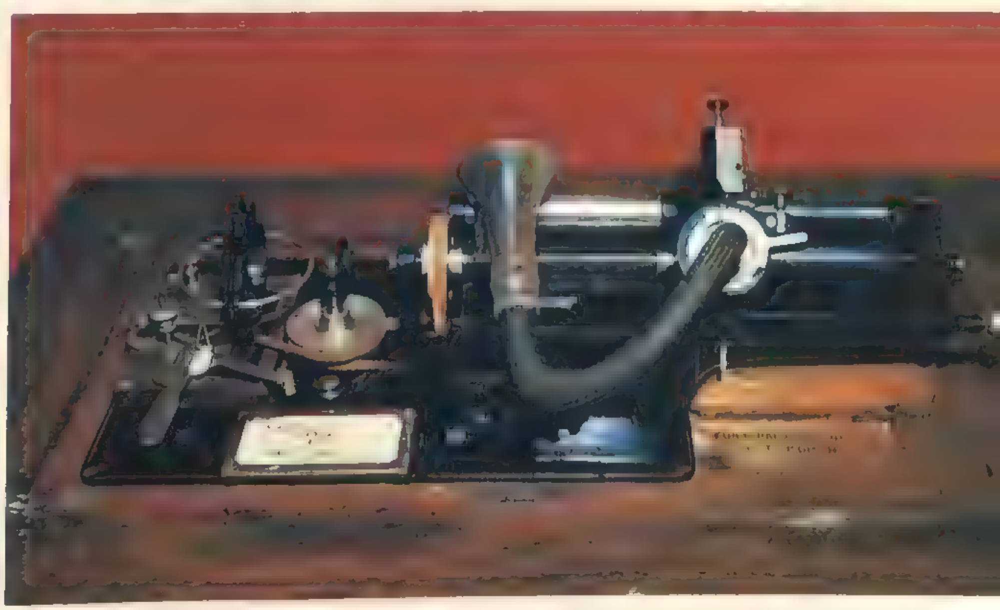
It would be impossible to list all Edison's inventions, from the magnetic separator of minerals to the taximeter and an improved model of the typewriter. The expanding activity of the works that produced many of his patents made it necessary to build a vast new industrial complex at West Orange, New Jersey.

During World War I, Edison was commissioned by the government to provide substitutes for important chemicals and in this way he entered the field of large-scale chemical production. Ford consulted him about the possibility of finding a vegetable species that could be substituted for *Hevea brasiliensis* as a gum latex in the manufacture of tires. Boldly venturing into the field of botany, Edison organized a search that covered 17,000 vegetable species. Moreover, as president of the Advisory Bureau for Naval Arms, he filed forty patents for instruments of war, a number of which were put into production.

It was only natural that a life of such intense work should leave him little time for his family. Two years after the death of his first wife, Mary Stilwell (he had married her in 1873 and she died in 1884), he married a friend's daughter, Mina Milner. He had three children by each wife, and the whole family lived in a magnificent house, Glenmont, at Llewellyn Park, near West Orange; his ceaseless activity, however, allowed him to spend only little time there.

"The man who never slept" made no distinction between night and day, for

The generator that Thomas Edison built to supply energy for his electric lamp was publicly demonstrated together with the lamp in December 1880 at Menlo Park, New Jersey.



Thomas Edison's first phonograph consisted of a steel cylinder covered with tinfoil, a metal point attached to a funnel, and a parchment diaphragm, which moved the point.

he spent almost all his time working and took only a few hours' sleep. He expected the same unflagging rhythm of work from his subordinates, though he was also understanding and cordial with them. He liked to chat and was never at a loss for a witty remark, but he did not like society life. He was extremely frugal in his habits; his only distractions were smoking, reading, fishing, and music.

His exceptional constitution allowed him to continue his intense activity until his death, which occurred when he was eighty-four. Although he defined himself as a "purely practical man," he introduced, in place of the empirical methods that were still in use in industry, a meticulous scientific approach and an efficiency based on organized and systematic research.

EGAS MONIZ. See Moniz, Antonio Caetano de Abreu Freire Egas.

EHRLICH, PAUL (1854–1915)

"Life, a Dream" was the theme for the commencement at Breslau High School in Germany in about 1870. It was a rhetorical and romantic theme undoubtedly well suited to the prevailing mentality of the century; but in the class that had to treat the subject that year, there was a pupil of independent mind who wrote an essay in the following vein: "Life may well be a dream, but dreams are, in fact, a chemical process, a kind of cerebral phosphorescence, and therefore have none of the romantic quality that those who know nothing about chemistry might expect." This original thesis dismayed the teachers so greatly that, despite his protests, they failed the rebel pupil. This schoolboy, Paul Ehrlich, came of a Jewish professional family, with liberal tendencies, from Strehlen, Silesia. His father was contemplative by temperament, whereas his mother was of a practical nature; and between the two of them Paul grew up with the conviction that the importance of scientific thought had to be upheld against the humanistic rhetoric that then prevailed in every field.

His uncompromising defense of this ideal did not facilitate the start of his career. As a medical student at the university in Breslau, he immediately achieved a reputation for what at that time seemed to be sheer eccentricity. He was very good at Latin but declared his hatred of classical culture and academic dissertations, and at every opportunity he hurried off to the laboratory to conduct experiments with dyes and anatomical parts.

He changed universities frequently, moving to Strasbourg, to Freiburg, and then to Leipzig. Finally he was able to devote himself to his dominant idea, that of studying the strange mechanism whereby dyes color tissues; in fact, the subject of his degree thesis in 1878 was "Contributions to the Theory and Practice of Coloring," which discussed the theory and technique of coloring histological preparations by means of aniline dyes.

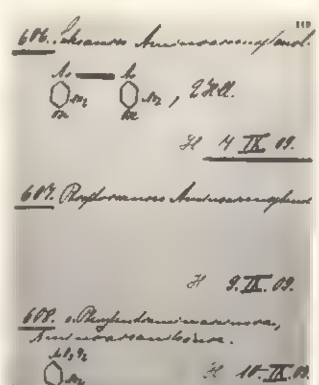
Although this work, which today ranks as one of the classics of medical literature, passed almost unnoticed at the time, it was not long before people started to talk about the strange doctor and his original experiments. He became known for his passionate interest in dyes and for his conviction that in the future they could be used for medical purposes. As a result of his discovery that a histological preparation dipped in a dye solution takes on color but not uniformly, the staining being intense in some places and much slighter in others, Ehrlich was convinced that it would be possible to combat bacteria and microbes of pernicious diseases by means of coloring substances. His reasoning was simple: if a dye chemically attacks a part of a tissue, selecting certain cells and discarding others, why would it not be possible to find a dye that could attack a microbe but would be rejected by the cells of the human organism; that is, poisonous for the microbe but innocuous for the organism that receives it? Since it was the microbes themselves that showed the existence of a chemical affinity between complex organic substances and the tissues of the human body (for example, the toxins of diphtheria bacteria attack the cardiac muscles, and those of tetanus attack the cells of the nervous system—a substance could well exist that was capable of attacking pathogenic agents selectively. But how could it be found?

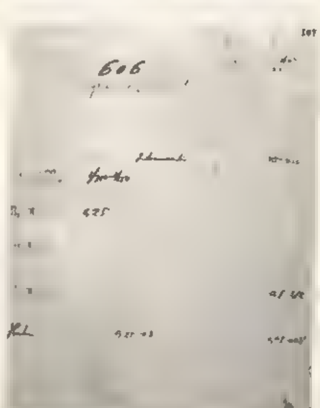
In 1887 Ehrlich fell ill with tuberculosis, which forced him to interrupt his studies, including, besides those on the specificity of attack of dyes, those on the staining of red and white corpuscles, important in the field of diagnosis, and those on the diazo reaction in urine, useful in the treatment of infectious diseases. Two years earlier, in 1885, some results of these studies had been assembled in the fundamental work *The Organism's Need for Oxygen* (1885). Seeking a hot climate for his health, he went to Egypt and there experienced a complete recovery.

After he returned to Germany, he joined the staff of his friend Robert Koch's Institute for Infectious Diseases, Berlin. Koch had discovered the bacillus of tuberculosis in 1882, and Ehrlich had shown him how to stain it distinctively, which proved to be an indispensable diagnostic tool.

In 1898 Ehrlich moved to Frankfurt am Main, where he carried on his search for a dye that, when injected into a laboratory animal, would save the victim from pathogenic germs. He had no set method for this but searched more or less at random among all the possible dyes. On reading about the research carried out by C. L. Alphonse Laveran, who had

In 1909, in collaboration with his Japanese assistant Hata, among others, and after 605 unsuccessful experiments and extensive note taking, Paul Ehrlich discovered a preparation that later proved effective against syphilis.





discovered that trypanosomes, the protozoa responsible for sleeping sickness, were vulnerable to arsenic, Ehrlich decided to combat the trypanosome.

After trying the dye benzopurpurine, without succe[illegible] decided to try new dyes and to [illegible] the benzopurpurine with the addi[illegible] of some substance that would make [illegible] soluble and effective in its attack on [illegible] terrible trypanosome. Through the [illegible]hesis of a benzopurpurine with s[illegible] groups, a successful remedy was [illegible] against trypanosome infection; b[illegible] soon became apparent that the mice [illegible] not completely cured, and in most c[illegible] they had relapses that proved fatal [illegible] a certain time. This showed that [illegible]ber of microbes had established t[illegible]lves in parts of the body that we[illegible] inaccessible to the medicine. Althou[illegible] research had to be abandoned, [illegible] principle discovered seemed to b[illegible]ect.

With help [illegible] the Speyer Foundation, Ehrlich was [illegible] to synthesize new dyes and new pro[illegible]. At one stage a new pharmaceuti[illegible]eparation, sodium arsanilate (Ato[illegible] was introduced; it was an arsenic p[illegible] supposedly lethal to trypanosome[illegible] proved so in experiments on an [illegible] but had the drawback of sometime[illegible]ding or even killing human bein[illegible]rlich modified some of the molecul[illegible] substances the reactions of which h[illegible] well, binding to them a benzene r[illegible] with an atom of arsenic, which form[illegible] basis of the sodium arsanilate p[illegible] After 605 unproductive experiment[illegible] research was finally successful in [illegible] The 606th preparation, arsphenam[illegible]ydrochloride, proved itself a sure remedy against the trypanosome infecti[illegible]

In 1905 the German microbiologist Fritz Richard Schaudinn had discovered the deadly spirochete responsible for syphilis and, in describing its place in the animal kingdom, had compared it with the trypanosome. Ehrlich, who followed all medical publications, was struck by this comparison and decided to try his 606th preparation against syphilis. It was found to be highly effective and was put on the market under the name Salvarsan. Subsequently, however, it was superseded by the antibiotics, which proved therapeutically more effective.

In 1908 Ehrlich shared the Nobel Prize in physiology or medicine with Ilya Mechnikov. It was awarded to them for their work on immunity. (*See* Ilya Ilich Mechnikov.)

EIGEN, MANFRED (1927–   )

The 1967 Nobel Prize in chemistry was shared by Manfred Eigen, chairman of the Max Planck Institute for Physical Chemistry, Göttingen, Germany; Ronald G. W. Norrish; and George Porter. The three were honored for "studies of extremely fast chemical reactions effected by disturbing the equilibrium by means of very short pulses of energy." Eigen's work centered on the instantaneous chemical changes that occur when an inorganic substance becomes an organic one, a subject involving the phenomena of the genesis of life itself. (*See* Ronald George Wreyforth Norrish; George Porter.)

Eigen, the son of a professional musician, was born in the city of Bochum in the industrial Ruhr. After several years at Göttingen University, first as a student and then as an instructor in chemistry, Eigen joined the nearby Max Planck Institute. At one time he was also a visiting lecturer at Cornell University, Ithaca, New York. For his contributions to chemistry he was awarded honorary degrees from the University of Chicago, Harvard, and Washington University, St. Louis, Missouri, and made a member of the Bunsen Society for Physical Chemistry, the Faraday Society, and the U.S. National Academy of Sciences.

EIJKMAN, CHRISTIAAN (1858–1930)

Research by the Dutch medical scientist Christiaan Eijkman into the deficiency disease beriberi led to the discovery of vitamins and to better understanding of nutrition. Eijkman shared the 1929 Nobel Prize in medicine or physiology with Sir F. G. Hopkins, British biochemist, for basic research in vitamins. (*See* Frederick Gowland Hopkins.)

Eijkman was the first to induce beriberi experimentally and to cure it. While serving in Batavia, Dutch East Indies (now Jakarta, Indonesia), as director of a research laboratory for pathological anatomy and bacteriology, Eijkman sought a causative germ for beriberi. The death rate from outbreaks of this disease, characterized by paralysis resulting from polyneuritis, sometimes reached 80 percent in the Dutch East Indies. In the course of his research, chickens that he was using suddenly developed a disease that acted like beriberi. He tried to find the germ responsible and to transfer the disease from sick to healthy chickens, but both efforts failed. The disease then disappeared.

It was learned that the chickens had fallen ill during a period of time when a cook was feeding them polished rice from the hospital supplies. When a new cook refused to give them food purchased for the patients and returned them to their diet of commercial feed, they recovered. With this knowledge Eijkman proceeded to induce the disease by feeding the chickens polished rice and to cure it by adding the discarded polishings or husks to their diet. He thought that the rice contained some sort of poison, and the husks, a neutralizer; but scientists later found that the husks contain an essential food factor now known as vitamin B_1, or thiamine.

Eijkman was born at Nijkerk, the Netherlands, the son of a schoolmaster. After graduating in medicine from the University of Amsterdam in 1883, he went to Berlin, Germany, to study bacteriology with Robert Koch and remained there until 1886, when he left for Batavia.

In 1898 Eijkman returned to the Netherlands to become professor of hygiene at the University of Utrecht, a position he held until his retirement in 1928. He was elected to the Royal Academy of Sciences of the Netherlands in 1907.

EINSTEIN, ALBERT (1879–1955)

German physicist Albert Einstein, one of the greatest scientists of all time, is best known for his theory of relativity; however, many other scientific contributions, especially his work in statistical mechanics, his quantum theory of radiation, and the photon theory of light, were revolutionary. For his photoelectric law and work in the area of theoretical physics, both of which came out of his 1905 paper on the photon, he was awarded the 1921 Nobel Prize in physics.

Einstein was born in Ulm, Württemberg, Germany; but his family moved to Munich when he was about five years old, and there he started school. When his family later moved to Italy, young Einstein stayed behind to finish public school in Munich and in Aarau, Switzerland. In 1896 he entered the Swiss Federal Polytechnic Institute in Zürich, where he studied to be a mathematics and physics teacher. Not immediately finding a teaching position when he graduated in 1900, he took a job as an examiner in the Swiss patent office in Bern; however, he continued his studies and in 1905 received his doctorate from the University of Zürich.

That same year Einstein also wrote four important papers. Each contained a monumental discovery in physics: the special theory of relativity; mass and energy equivalence; the theory of Brownian motion; and the photon theory of light.

The next few years found Einstein very active in scientific and teaching endeav-

ors. In 1909 he became a professor at the University of Zürich, in 1910 he joined the German University in Prague, and in 1912 he returned to the Swiss Federal Polytechnic Institute. The following year he became professor at the University of Berlin, the director of the Kaiser Wilhelm Physical Institute, and a member of the Prussian Academy of Sciences in Berlin. During the next several years he did serious work in relativity and in 1916 published his famous paper on the general theory of relativity. He also did extensive work in the field of radiation and statistical mechanics.

Two scientists who had much in common were Albert Einstein and Irène Joliot-Curie, especially in regard to nuclear physics.

After the publication of his general theory of relativity, Einstein was appointed to the Intellectual Cooperation Organization of the League of Nations in 1922. In the 1920s he developed his unified field theories based on the idea that the laws of gravitation and electromagnetism can be explained by a single geometric formula involving space and time. He published his unified theory in 1929 and a generalized theory of gravitation in 1949.

Einstein moved to the United States after the rise of Nazism in Germany. Finding, upon his return to Germany after a short visit to California in 1932, the Nazis gaining power, he resigned his several posts and accepted a lifetime position at the new Institute for Advanced Study in Princeton, New Jersey, in 1933. He became a U.S. citizen in 1940

Einstein's work made him one of the pioneers of the atomic age. His theories were used in producing the bomb. In his general theory of relativity he had treated matter and energy as equivalent, thus establishing the concept for splitting the atom. He was also responsible for the ultimate development of the atomic bomb by the United States. Two German physicists had discovered the fission of uranium in the 1930s, and the possibility of Germany's developing a bomb based on the findings frightened some of Einstein's scientist friends. They asked the great physicist to alert U.S. President Franklin D. Roosevelt to the dangers were Germany to develop the bomb. Einstein warned Roosevelt in a letter that Germany was developing nuclear fission, and it was this letter that led to the creation of the Manhattan Project, a $2 million federal program for atomic research.

Einstein's contributions to physics were many and complex. One of his main aims was to geometrize physics. In his special theory of relativity he showed how the laws of mechanics must embrace the laws of magnetic fields, later concluding that electromagnetic fields are influenced by gravitational fields. His principle of equivalence involving mass and energy was to become the basis of his general theory of relativity. He developed physical laws describing the behavior of fast elementary particles, the bending of light rays in gravitational fields, the changing of light frequencies in gravitational fields, the thermal motion of molecules, the molecular constitution of matter, and the thermal properties of light.

Einstein lived a quiet, simple life and was known for his compassion and his interest in human affairs and social justice. He enjoyed music and played the violin. Although an advocate of Zionism, he turned down the presidency of Israel offered to him in 1952. Einstein was married twice. His first wife was Mileva Meric, whom he married after graduating in 1900. They had two sons. The marriage ended in divorce shortly after he began working in Berlin; and during World War I he married his first cousin Elsa, who had two daughters by a previous marriage.

Among Einstein's published works can be found *The Meaning of Relativity* (1928), *About Zionism* (1931), *Builders of the Universe* (1932), *On the Method of Theoretical Physics* (1933), *Why War?* (with Sigmund Freud; 1933), *The World as I See It* (1934), *The Evolution of Physics* (with Leopold Infeld; 1938), and *Out of My Later Years* (1950).

EINTHOVEN, WILLEM (1860–1927)

The major contributions of Willem Einthoven, Dutch physiologist, to the development of electrocardiography were rewarded with the 1924 Nobel Prize in physiology or medicine. In 1903 Einthoven devised an instrument that made accurate electrocardiograms possible for the first time.

Einthoven was born in Samarang, Java, where his father was a practicing physician. After the father's death in 1870, the Einthoven family moved to Utrecht, the Netherlands. There Willem was educated at the Utrecht State University, qualifying in medicine in 1885. At the age of twenty-five he went to Leiden University as professor of physiology, a post he held until his death.

Einthoven's chief interests were related to electric phenomena that arose in the heart. He constructed a string galvanometer and used it to record the electrical activity of the contracting heart muscle and to register graphically the sounds of the heart. He pioneered in developing electrode arrangements, or lead systems, for the registration of electrocardiograms in man. The limb leads that he described and used—right arm and left, right arm and left leg, and left arm and left leg—have remained the standard recordings. Einthoven was concerned primarily with principles of physics, but he knew the effectiveness of his method in diagnosing coronary disease.

EKMAN, VAGN WALFRID (1874–1954)

Research by the Swedish oceanographer and physicist Vagn Walfrid Ekman has been of lasting value to both oceanography and meteorology. He is best known for his qualitative explanation of ocean-current distribution, the Ekman spiral. He was also the inventor of a meter for measuring ocean currents.

After receiving his doctorate at Uppsala University, Sweden, in 1902, Ekman served as assistant at the International Laboratory for Oceanographic Research, Oslo, Norway, until 1908. During that time, Ekman explained the hindrance to a ship's progress known as dead water; conducted the experiments that were the basis for the tables of compressibility of seawater; and invented the mechanical current meter, which is known by his name. From 1910 to 1939 he was professor of mechanics and mathematical physics at Lund University, Sweden.

In 1905 Ekman published a classic in his special field, "On the Influence of the Earth's Rotation on Ocean-Currents." It deals with the currents produced by wind friction on the ocean surface. In the ocean the uppermost layers are dragged along with the surface wind. Because of the vertical exchange of momentum caused by the eddies, the water

in the lower layers is also dragged along. Another turning of the current with increasing depth accompanies the changed velocity of distribution.

ELTON, CHARLES SUTHERLAND (1900–)

The British ecologist Charles Sutherland Elton was instrumental in establishing the principles and concepts of modern ecology. He was responsible for suggesting the study of animals and plants in ecosystems. He elaborated and clarified the relationships of organisms in food webs and food chains. In addition, he formulated many concepts regarding biotic communities.

Elton was educated at Liverpool College and at New College, Oxford, where he was a reader in animal ecology from 1936 to 1967. In that same period he was also senior research fellow at Corpus Christi College, Oxford, being named an honorary fellow in 1967. In addition, he served as director of the Bureau of Animal Population, Department of Zoological Field Studies, from 1932 to 1967.

He made several expeditions in search of new ecological insights. In 1921 he was an ecologist on the Oxford expedition to Spitsbergen, a Norwegian possession in the Arctic Ocean. He also participated in the Oxford Arctic expedition in 19[illegible] and the Lapland expedition in 1930.

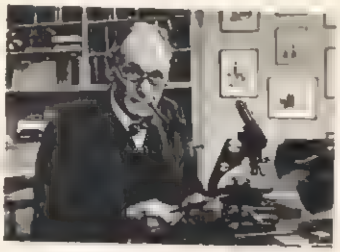
In 1958 Elton was elected a fellow of the Royal Society. The Linnean Society awarded him a gold medal in 1967. He was named an honorary member of the American Academy of Arts and Sciences in 1968.

Elton was a prolific author. His books include *Animal Ecology* (1927), *Exploring the Animal World* (1933), and *The Pattern of Animal Communities* (1966).

ENDERS, JOHN FRANKLIN (1897–)

For cultivating the poliomyelitis virus in test-tube cultures of various mammalian tissues, John Franklin Enders, U.S. microbiologist, shared in the 1954 Nobel Prize in physiology or medicine. The achievement by Enders and his co-winners, F. C. Robbins and T. H. Weller, led not only to development of a polio vaccine but also to isolation of many other viruses.

Until the fruitful collaboration of Enders and his associates, technical problems prevented widespread use of tissue culture in virology. To study a virus, scientists had to inoculate experimental animals, observe their reaction, and make inferences—a long and inadequate procedure. (*See* Frederick Chapman Robbins; Thomas Huckle Weller.)



John Enders

Enders, a banker's son, was born in West Hartford, Connecticut. After serving as a navy pilot in World War I, Enders received a bachelor's degree from Yale in 1920 and a master's degree in English literature from Harvard in 1922. Turning to science, he was awarded his doctorate in bacteriology and immunology at Harvard in 1930.

In his early research Enders shed new light on the study of tuberculosis, pneumococcal infections, and resistance to bacterial diseases. He concentrated later on viral diseases. Seeking ways to grow viruses in test tubes or flasks, he experimented with tissue culture. In 1946 he established the research division of infectious diseases at Children's Hospital in Boston, Massachusetts. There, in 1947, he, Robbins, and Weller began to study ways of producing the polio virus in quantity. It was generally believed that polio viruses could live only in nerve cells and tissue, but Enders and his group had doubts about the existence of such an affinity. They disproved it when a monkey developed paralysis of the legs after an inoculation with polio virus grown in a culture of human embryonic skin and muscle tissue.

With further research Enders and his colleagues discovered that the polio virus damaged cultured cells; tissues originally infected with the virus strain showed widespread degeneration. Inoculation of experimental monkeys was no longer necessary for demonstrating multiplication of the polio virus.

The work by Enders and his group stimulated research into other viral diseases. They themselves produced the first vaccine against the measles virus in the late 1950s. In 1956 Enders became a professor at Harvard. He was honored in 1953 with membership in the National Academy of Sciences.

ERATOSTHENES (274?–?194 B.C.)

At the height of Hellenistic culture, which was a culture of consolidation and specialization, there appeared one thinker who had an encyclopedic mind, one who was destined to make a fundamental contribution to numerous sciences and to be despised by his contemporaries. The genius of Eratosthenes was so versatile that it was not until the Renaissance, a time of intellectual boldness, that it was understood and appreciated.

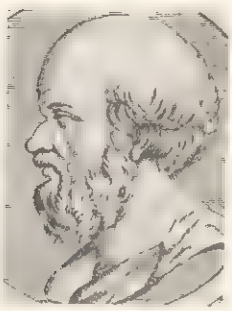
The city of Cyrene, on what is now the Libyan coast, was the center of the Hellenistic world when Eratosthenes was born there, supposedly at about the time of the 126th Olympiad. Although nothing is known of his childhood, there is some information available regarding his studies. He had his earliest education at Cyrene and then went to Alexandria, where his teacher was the famous poet Callimachus.

Although the Greek scientist Eratosthenes was the first man to measure the diameter of the Earth, he is perhaps best known for his system of making tables of prime numbers.

Finally he went to Athens, where his teachers were Arcesilaus, Ariston, and Bion. These men were not mathematicians or scientists but philosophers and men of letters. Through them Eratosthenes came into contact with the ideas of Plato. This philosophical and literary education evidently awakened a great deal of Eratosthenes' interest, because half his works were basically philological, historical, and philosophical.

On his return to Egypt, Eratosthenes was made director of an enormous library in Alexandria belonging to the Ptolemaic dynasty. Living constantly surrounded by books gave him a chance to develop his many interests and to become a polymath and, in fact, a walking encyclopedia. In the library he no doubt came across books on astronomy and geometry,

and he also had an opportunity of meeting all the scholars who visited the library. In this way there grew up that interest in the exact sciences that enabled him to become, among other things, the first man to calculate the diameter of the Earth.



Eratosthenes

Eratosthenes, who lived in Alexandria but often used to go to the city of Syene (now Aswan), had noticed that at a certain time of year when the sun's rays fell perpendicularly on the one city, they fell obliquely on the other. It is not hard to understand this if it is remembered that the Earth is spherical: when the sun is perpendicularly above one point of this sphere, it simply cannot be perpendicularly above other points at the same time. Eratosthenes went even further: he thought that if one measured the amount that the rays departed from the vertical in the one city while they were, in fact, perpendicular in the other, one would be able to work out the difference in latitude between the two cities, which lie almost in a straight line north and south. In this way one would find out the arc of the meridian separating the two cities; and if one knew the linear distance between them, one would be able to calculate the length of the whole meridian of the Earth, which, in turn, would lead to the solution of its diameter. Eratosthenes, then, lost no time in measuring the distance between the two cities, as well as the angle of the rays in one place when they were perpendicular in the other, and, thus, was able to measure the length of the arc of the meridian. He found that one meridian degree was equal to about 120 kilometers, but it is now known to be a little more than 110. All the same, his mistake does not seem so great when it is realized that a great deal of uncertainty in evaluating his results comes from today's imperfect knowledge as to how to convert his units of measure accurately into modern-day ones. At all events, he managed to arrive at the first fairly accurate assessment of the Earth's diameter.

Besides his calculation of the Earth's diameter, Eratosthenes discovered some other notable things in mathematics. Unfortunately, his writings have not survived, but it is known from a fragment of a letter written to Ptolemy that he was working on doubling the cube (finding the length of the side of a cube double in volume to a cube whose side measurement is given, a problem that cannot be solved with ruler and compass). In this letter he lists the solutions then known for this problem and goes on to suggest one of his own, based on the use of the mesolabe, a special instrument made of mobile triangular pieces.

His name is also linked with a method of making tables of prime numbers. Although a simple method, it is still used today. It consists of making a list of all the uneven whole numbers in succession and then—making use of their positions—canceling the multiples of three, five, seven, and the higher prime numbers. This method, which is called Eratosthenes' sieve, has perhaps made his name more famous than all his other works. No one has as yet discovered a less empirical method of making tables of prime numbers.

The versatility of Eratosthenes was, unfortunately, not in the least appreciated by his contemporaries, who thought that his was an inferior mind because it was dispersed in so many activities instead of concentrating on one thing. For this reason his detractors often used to dub him the Beta, after the second letter of the Greek alphabet, to imply that he was second best; or to pour scorn on his universal and encyclopedic knowledge, they would call him Pentatlos, like the athlete who took part in five competitions instead of trying to excel at one.

Naturally, Eratosthenes had not only detractors but also numerous admiring friends. Among these was the great Archimedes, who often used to go to Alexandria to see him. Archimedes was proud of his friendship with Eratosthenes, whom he regarded as a supreme mathematician, and dedicated his studies to him, so that they might feel linked together by an intellectual bond. Sometimes he even invented problems and dedicated the solutions to Eratosthenes.

Eratosthenes is said to have committed suicide at the age of eighty because of desperation at having lost his sight.

ERLANGER, JOSEPH (1874–1965)

Discoveries by U.S. physiologist Joseph Erlanger about the functional variance in nerve fibers of differing diameters were rewarded with the 1944 Nobel Prize in physiology or medicine. The co-winner was H. S. Gasser, Erlanger's colleague and former student.

Erlanger and Gasser, who devised new techniques for amplifying and recording electric impulses in nerves, were able to show that nerve fibers conduct electricity at rates varying directly with the thickness of the fiber. The results of their research, *Electrical Signs of Nervous Activity* (1937), is a classic in the field of neurophysiology. (See Herbert Spencer Gasser.)

Erlanger was born in San Francisco, California, and graduated from the University of California as a chemistry major in 1895. After receiving his medical degree in 1899 from Johns Hopkins University Medical School, Baltimore, Maryland, he joined its physiology department. His first appointment as a professor was at the newly organized medical school of the University of Wisconsin, Madison, where he also reorganized the physiology department. Gasser became one of his students. From [illegible] until his retirement in 1946, Erlanger was professor of physiology at Washington University, St. Louis, Missouri, and Gasser again joined him.

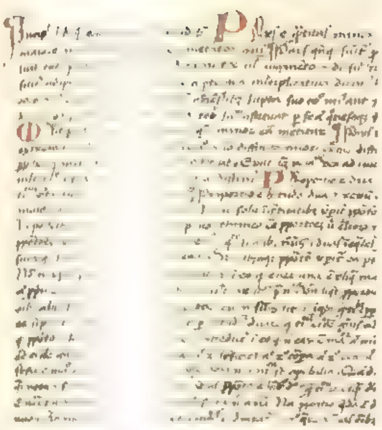
In 1921 they began their work on the electrical properties of nerve fibers. Using a cathode-ray oscilloscope to amplify the passage of electric impulses through isolated nerve fibers, they learned that different fibers conduct their impulses at different rates.

Erlanger also conducted experiments that led to the modern view that conduction in myelinated nerve fibers is not continuous but moves in leaps, or jumps. (Myelin is a soft, white, fatlike substance that covers the fibers of motor or sensory nerves.) Erlanger published more than 100 papers on neurophysiological subjects. In addition, he made contributions to the field of circulatory physiology, including a graphic method for measuring blood pressure. He was elected to the National Academy of Sciences in 1922.

EUCLID (about 300 B.C.)

For more than 2,200 years the teaching of geometry was dominated by the work of the Greek mathematician Euclid. All that is known of his life is that he founded a school at Alexandria during the reign of Ptolemy I, from 306 B.C. to 283 B.C.

Euclid called his basic text *Elements*. It was published in thirteen books; it seems certain that books fourteen and fifteen were appended by later geometers. Euclid was not a great original thinker. Instead, he gathered together



Euclid's *Elemen*[illegible] [illegible]mposite of the mathematical knowlec[illegible] the time of the great scholar, is the [illegible] [illegible]ndamentally important study of geome[illegible]

Euclid

the thinking [illegible] work of many other mathematicia[illegible] organized the material into a [illegible] form. He first presented axiom[illegible] postulates, then theorems. Two m[illegible]naticians whose work he drew on [illegible] were Eudoxus and Theaetetus.

The work [illegible]clid was not limited to geometry. H[illegible] delved into ratio and proportion a[illegible] what is now called the theory of nu[illegible]bers, proving that the square root [illegible] is irrational and that the number of pri[illegible] is infinite.

For centuries, mathematicians thought that Euclid's work represented fixed, unchanging truth. Euclid said, for example, that parallel lines are always parallel and if extended infinitely will never meet in space. Later mathematicians recognized that this represents a common agreement but is not always true. Non-Euclidean geometries were developed in the nineteenth century.

EUDOXUS (400?–?347 B.C.)

The ancient Greek scientist Eudoxus was a man of many talents. Though primarily a mathematician, he was also an astronomer, a geographer, a physicist, a physician, and a legislator.

Diogenes Laërtius wrote a biography of Eudoxus; but it is inaccurate, and there is still uncertainty about many details of his life. It is known, however, that he was born in Cnidus, on the coast of present-day Turkey, and lived in poverty. He studied at Tarentum with the esteemed mathematician Archytas and at Plato's Academy in Athens, Greece, possibly even serving as its head in Plato's absence. At one time he spent about sixteen months studying astronomy in Egypt. He then established his own school in Cyzicus, in present-day Turkey, but later moved it to Athens.

His method of exhaustion could be applied to many theorems in geometry. He formulated a new definition of proportions, which paved the way for a new theory of proportion applying especially to incommensurables. He defined equal ratios and provided the beginning of one modern theory about irrationals. Many of his geometric proofs were summarized later by Euclid; it is thought that Euclid's twelfth book is based largely on the work of Eudoxus (*See* Euclid.)

As an astronomer, Eudoxus made a star map that remained unequaled for centuries. He also made a model of twenty-seven spheres and advanced the idea that the motion of each planet was the result of the motions of four spheres placed one within the other so that each sphere revolved around its own axis while at the same time participating in the motions of the other three spheres linked with it, each of which was also revolving on its own axis. The sun and the moon needed three spheres each; the fixed stars, only one. In this way Eudoxus could account theoretically for what he could observe: that the orbits of the planets and the stars are irregular. Plato had maintained that planets orbit in perfect circles, and Eudoxus attempted to reconcile this theory with the known facts.

Among his other contributions were a new map of the known world and a seven-volume geography. He also made some improvements in the calendar and gave a revised estimate of the length of the solar year.

At least one of his theories had an influence on Aristotle. Eudoxus theorized that pleasure is the highest good, and Aristotle discussed this idea in a treatise on ethics. It is possible that Aristotle's theory of the prime mover was also influenced by Eudoxus.

EULER, LEONHARD (1707–1783)

The most prolific mathematician of all time was Swiss-born Leonhard Euler. He was a founder of modern analysis, and his two-volume text on analysis was as influential in its time as was Euclid's *Elements* in ancient times. The trend to emphasize arithmetic in mathematics and physics was promoted by Euler and continues at the present time.

His best work was concentrated in pure mathematics. He is remembered for his theorems and notations, from elementary geometry to advanced calculus. Through his work the symbols e, i, and π came into common use; and delving into the theory of numbers, he discovered the law of quadratic reciprocity in 1772.

Euler was born in Basel, Switzerland, the son of a minister. Like his father, Euler studied theology and Hebrew; but in addition, he also received private lessons in mathematics from Jean Bernoulli and became friendly with his sons.

Because of his connection with the Bernoulli family, he was invited in 1727 by Empress Catherine of Russia to become an associate of the Academy of Sciences in St. Petersburg. In 1730 he was promoted to professor of physics and in 1733 succeeded Daniel Bernoulli as professor of mathematics. Two years later he lost the sight of an eye but continued working hard and writing profusely.

His stay at Catherine's court had its lighter moments. The French philosopher Denis Diderot was at court advocating atheism, much to Catherine's annoyance.

The Swiss mathematician Leonhard Euler was one of the founders of pure mathematics; but he wrote on many subjects, ranging from algebra to astronomy, optics, and acoustics

Vollständige
Anleitung
zur
Algebra
von
Hrn. Leonhard Euler.
Zweyter Theil.
Von Auflösung algebraischer Gleichungen
und der unbestimmten Analytic.

St. Petersburg.
gedruckt bey der Kays. Acad. der Wissenschaften 1770.

At her instigation Euler made up an equation that "proved" the existence of God and challenged Diderot to reply. Knowing nothing about mathematics, Diderot could not rebut the equation and was laughed out of court.

Leonhard Euler

Upon Frederick the Great's invitation in 1741, Euler became a member of the Academy of Sciences in Berlin and stayed there for twenty-five years, accomplishing a tremendous amount of work. In 1766 he returned to Russia. He soon became blind in his other eye; but his work continued, aided by a fantastic memory and a phenomenal ability at mental calculation.

EULER, ULF SVANTE VON (1905–)

The Swedish physiologist Ulf Svante von Euler shared the 1970 Nobel Prize in physiology or medicine for discovering that the substance noradrenaline is the impulse transmitter at the nerve terminals of the sympathetic nervous system. He demonstrated also how the substance is stored within the nerve fibers of the system. Sharing the Nobel award with Von Euler were the U.S. biochemist Julius Axelrod and the British biophysicist Sir Bernard Katz. The three men worked independently on the chemistry of nerve transmission. (See Julius Axelrod; Sir Bernard Katz.)

Von Euler, the son of Hans von Euler-Chelpin, who shared the 1929 Nobel Prize in chemistry, was born in Stockholm. On receiving his medical degree in 1930 from the Royal Caroline Institute in Stockholm, he remained there as a professor of physiology. He also studied abroad on fellowships at universities in Great Britain, Belgium, and Argentina.

From 1953 to 1960 Von Euler was a member of the Nobel Committee for Medicine, the last two years as chairman; from 1961 to 1965 he was general secretary of the Nobel Foundation, which administers prize funds but is not involved in the selection of laureates; and after 1966 he served as president of the foundation. Although a member of the prize-awarding body by virtue of his association with the Caroline Institute, he was not present when he was elected a recipient of the prize.

Von Euler's discovery in 1946 about the neuro-transmitter noradrenaline laid the groundwork for Axelrod's work on the mechanisms that regulate the formation and inactivation of noradrenaline in the nerve cells. According to the award committee, Von Euler's scientific discoveries increased the knowledge of transmission in the sympathetic nervous system, formed the basis for understanding transmission in the central nervous system, and stimulated the search for remedies against the various nervous and mental ailments.

Besides the Nobel Prize, Von Euler received many other honors, including the Swedish Order of the North Star. In 1967 he shared the $50,000 Stouffer Prize with three other scientists for contributions to the understanding of high blood pressure and hardening of the arteries.

EULER-CHELPIN, HANS KARL AUGUST SIMON VON (1873–1964)

In recognition of his research on enzymes, Hans Karl August Simon von Euler-Chelpin was awarded the 1929 Nobel Prize in chemistry jointly with Sir Arthur Harden, British biochemist. Euler-Chelpin was the first scientist to work out the structure of Harden's coenzyme—the nonprotein molecule that is necessary for activating the enzyme. (*See* Sir Arthur Harden.)

During his experimentation on coenzymes, beginning in 1923, Euler-Chelpin contributed significantly to the understanding of the biochemistry of sugars and phosphates. After isolating cozymase, the coenzyme of zymase—a mixture of yeast-produced enzymes that causes sugar fermentation—he determined its chemical nature, showing that it contains phosphoric acid with a sugar residue and a purine residue, and devised a method to measure its purity.

Euler-Chelpin was born in Augsburg, Germany. Originally, he was interested in painting but turned to chemistry and studied in Munich, Würzburg, Berlin, and Göttingen, and at the Pasteur Institute in Paris, France. His teachers included the Nobel laureates Walther Hermann Nernst and Jacobus Henricus van't Hoff. In 1897 he became assistant in physics to S. A. Arrhenius, another Nobel Prize winner, in Stockholm, Sweden. In 1900 Euler-Chelpin was appointed lecturer in physical chemistry, and from 1906 to 1941 he was professor of general and inorganic chemistry [illegible] University of Stockholm, after which he became professor emeritus.

Besides studying the workings of enzymes and coenzymes [illegible] helped determine the structure of [illegible]al vitamins. He published on the [illegible]s of physical and organic chemistry [illegible] biochemistry. Euler-Chelpin was a member of the Swedish Academy of Sciences and of many other learned organizations.

EVANS, OLIVER (1755[illegible]

In the eighteenth century a young man from rural Delaware successfully anticipated twentieth-century methods of automation. The chief contribution of Oliver Evans to progress involved his improvements in steam engines and the first steam-powered vehicle [illegible] travel on U.S. land was of his invention.

Evans was born on a [illegible] near Newport, Delaware. At the age of fifteen he was apprenticed to a [illegible]nmaker but studied mathematics and mechanics in his spare time. In 1777, when employed in the manufacture of [illegible] teeth for carding wool, Evans invented a machine that turned out 1,500 ca[illegible] per minute. A few years later Evans joined his brothers in the operation of a flour mill in Wilmington, Delaware, and soon he had the power of the water wheels doing all the work.

In 1785 Evans built a water-powered flour mill that performed every operation in converting wheat into flour. A system of conveyors and elevators moved the raw material, meal, and flour on a continuous production line.

Evans continued, meanwhile, with his study of steam power. In 1789 he was granted the first U.S. patent for a steam-propelled land vehicle, but after 1800 he concentrated on stationary engines. By 1802 he had a high-pressure engine operating in his mill.

In 1803 Evans built for the city of Philadelphia a steam-powered dredging scow that foreshadowed both the automobile and the steamboat. The boat that contained the dredge was mounted on wheels and could move under its own power both on land and in the water. Evans personally steered the machinery-laden scow through the streets of Phila-

delphia from his shop to the Schuylkill River. In 1807 he founded in Philadelphia an ironwork for the construction of engines and oth[illegible] industrial machinery.

FABRE, JEAN [illegible]RI (1823–1915)

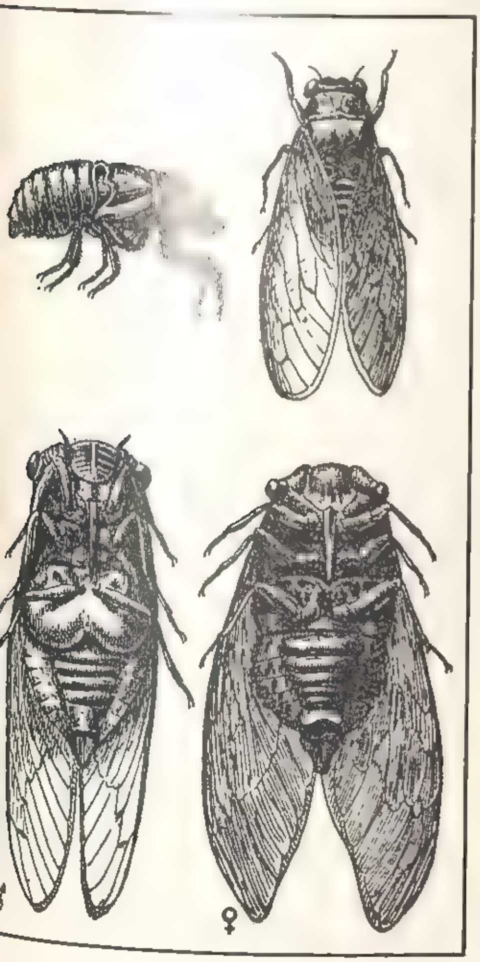
One of his [illegible]graphers called Jean Henri Fabr[illegible] [illegible]t of science." Fabre, a French ent[illegible]st, wrote literate essays on the [illegible] history of insects.

In his ten-[illegible] *Souvenirs Entomologiques* he di[illegible]uch questions as the relationship between the human mind and the animal mind. All of his writings were based on a firm foundation of direct observation. He concentrated on hymenoptera, coleoptera, orthoptera, and spiders. His study of animal life led him to oppose the evolutionary theory of Charles Darwin, who, however, was apparently an admirer of Fabre's insect studies.

Fabre was born in Saint-Léons, France. After studying at the Normal School in Vaucluse and also at Rodez, he taught at Carpentras, at the college of Ajaccio on Corsica, and at the *lycée* in Avignon, meanwhile earning his doctorate in Paris. At the relatively young age of forty-nine he retired to Sérignan to devote all of his time to the study of insects.

Jean Fabre

Included amo[illegible] [illegible]awings that appeared in Jean Henri F[illegible] *[illegible]evastators*, a small volume of essay[illegible] [illegible]cts that were then considered harm[illegible] [illegible]riculture, were sketches of the cicad[illegible] [illegible]g the larval stage, the dorsal side of [illegible] [illegible]dult, and the ventral side of both the a[illegible] [illegible]male and female. Fabre's principal work [illegible]ever, was the ten-volume *Souvenirs Ento[illegible]giques* (1879–1907), which, in a lively, cha[illegible] [illegible] style, summarized many years of care[illegible] [illegible]servations, experiments, and reflection[illegible] [illegible]nsects and their ecology.



FARADAY, MICHAEL (1791–1867)

The English chemist and physicist Michael Faraday discovered the laws of electrolysis. He also discovered electromagnetic induction and formulated the basic similarities between light and magnetism. Calling himself a natural philosopher, he did all his complex studies with virtually no knowledge of mathematics.

Faraday was born in Newington, Surrey, England. His family was poor, as well as large. At age fourteen he was apprenticed to a bookseller, who lent him science books to read, and by twenty-one he was assistant to the renowned chemist Sir Humphry Davy at the Royal Institution.

Two chlorides of carbon and a new compound of carbon, iodine, and hydrogen were discovered by Faraday in 1820. Three years later he liquefied chlorine. Sir Humphry felt that he had given Faraday the basic idea for this feat and became angry at him for not acknowledging the debt. When Faraday was elected a fellow of the Royal Society in 1824, Sir Humphry cast the only negative vote.

In 1825 Faraday isolated benzene; this was to be his greatest contribution to organic chemistry. In that same year he was named director of the laboratory at the Royal Institution.

Beginning in 1831 he performed some famous experiments. In one of these he wound two coils of insulated wire around an induction ring of soft iron. One coil was connected to a battery, the other to a galvanometer. When a circuit was made or broken with the battery, the galvanometer indicated a current.

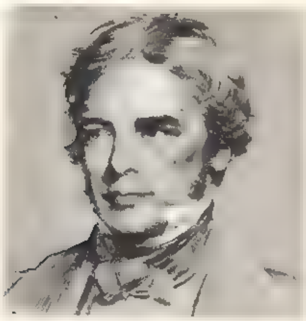
During this period he also made the first dynamo, or simple electric generator. He rotated a copper disk between the poles of an electromagnet. Current was generated through the touching of the axis and the rim of the disk. This was the first step toward a generator that would provide a plentiful, cheap supply of electric current.

To explain some of his work, Faraday developed the concept of magnetic lines of force. In his view, magnetic force branched out in all directions from its source, the electric current; and these lines of force formed a magnetic field. This was the germ of the idea of various fields that became so important to modern science.

In 1832 Faraday announced his laws of electrolysis. He had sent an electric current through molten metal com-

Coils of insulated wire were used by the English chemist and physicist Michael Faraday in some of his famous experiments on electromagnetic induction in 1831.

pounds and then had analyzed the results. He coined the words *electrode*, *anode*, and *cathode*, which are now standard in scientific vocabulary.



Michael Faraday

In his honor the unit of electrostatic capacitance is called the farad. The quantity of electricity needed to liberate the equivalent weight of an element is called the faraday.

A deeply religious man, Faraday belonged to a sect called the Sandemanians. Modest about receiving honors, Faraday declined the presidency of the Royal Society, as well as knighthood.

FERMAT, PIERRE DE (1601?–1665)

Mathematics was only the hobby of Pierre de Fermat of France, but he has been favorably compared with the great Sir Isaac Newton. Fermat was reluctant to publish his findings, and many of his papers were lost. It is interesting to speculate what he could have accomplished had he been a professional, full-time mathematician who systematically organized and published his work.

Fermat was born in Beaumont-de-Lomagne, France. He studied with a private tutor and also at Toulouse. In 1631 he was made counselor of the parliament of Toulouse but pursued mathematics as an avocation.

Thirteen years before Newton was born, Fermat had the basic idea of differential calculus. As a result of his work with Blaise Pascal, the theory of probability arose. In 1629 Fermat discovered the fundamental principle of analytic geometry; but he did not publish this information, and René Descartes, who published the basic principle of analytic geometry in 1637, is generally credited with its discovery.

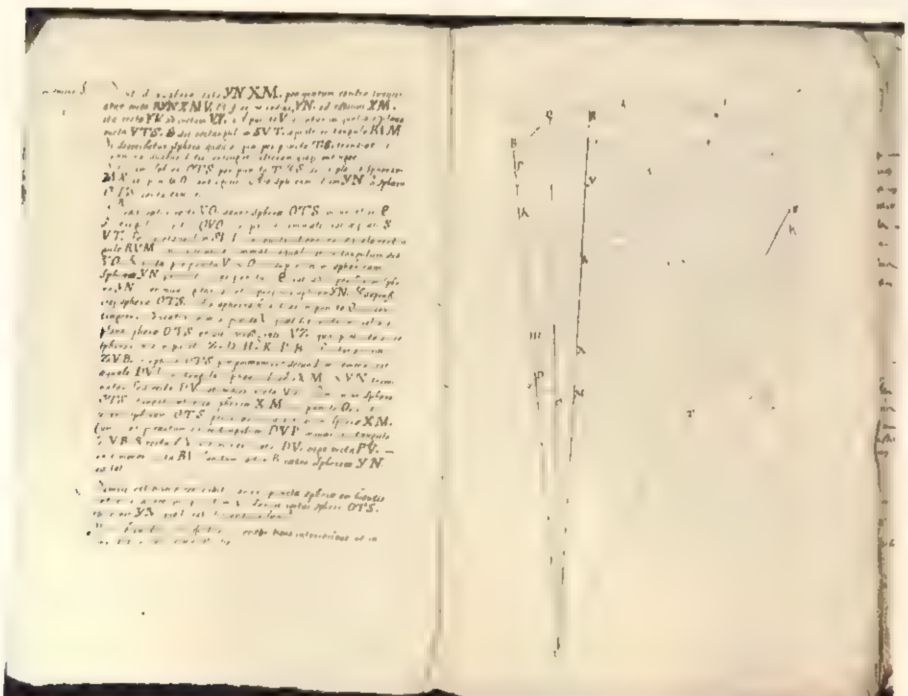
The theory of numbers occupied much of Fermat's energy. He was absorbed in discovering the properties of numbers through this "higher arithmetic." Two theorems in the theory of numbers bear his name. The first, called the lesser Fermat theorem, is based on his statement about primes. As defined by Fermat, a prime is any number greater than one and that can be evenly divided only by one and by the number itself; for example, 2, 3, and 5 are primes.

The other theorem, known as Fermat's

Pierre de Fermat

last theorem, remains o… of the great unsolved problems of m… matics. If n is a whole number great… han 2, there are no values among th… le numbers x, y, and z that can sol… he equation $x^n + y^n = z^n$. He wrote … theorem in the margin of a book and … d that there was not enough room i… e margin to write the proof. In the ea… 900s a German professor offered a … cash prize to anyone who could su… a proof for Fermat's last theorem, b… far no one has been able to discover… proof. Fermat's notes were publish… sthumously by his son. A comprehe… edition of his works was edited b… ul Tannery and Charles Henry and … lished from 1891 to 1922.

Although mathematics was actually only an avocation to Pierre de Fermat, he was the greatest number theorist between Diophantus and Leonhard Euler, and his contributions to mathematics were many. Besides his work with the theory of numbers, he discovered the fundamental principle of analytic geometry and was the inventor of differential calculus.



FERMI, ENRICO (1901–1…

The atomic era began … 1942 when the first controlled nuclea… in reaction was achieved under the direction of Enrico Fermi, Italian-American physicist. He had won the 1938 Nobel Prize in physics after great success in producing artificial radioactivity and in analyzing the decay products.

Fermi was born in Rome, Italy. After earning his doctorate from the University of Pisa in 1922, he studied for a time at the universities of Göttingen, Germany, and Leiden, the Netherlands. He lectured in mathematical physics at the University of Florence from 1924 to 1926, and in 1927 he became professor of theoretical physics at Rome University.

Early in his career, when he was concerned with theoretical physics, Fermi discovered the statistics valid for particles obeying the exclusion principle of Wolfgang Ernst Pauli. Later, Fermi developed the theory of beta decay of nuclei, giving mathematical evidence for Pauli's idea of the neutrino—a subatomic particle emitted along with electrons

from certain atomic nuclei during such nuclear reactions as beta decay.

Turning to [illegible]imental work, Fermi became intere[illegible]n the newly discovered neutron. [illegible]nd that he could induce artificial [illegible]ctivity by bombarding the nucleu[illegible]n atom with neutrons and began a [illegible]atic study of the effect of neut[illegible]nbardment on each element. Fe[illegible] his colleagues discovered slow[illegible]rmal, neutrons and their propert[illegible] work was of paramount impo[illegible] his future feat because it indi[illegible]w the speed of nuclear reactio[illegible]t be controlled.

Political c[illegible]s in Fascist Italy had made Ferm[illegible]nined to leave the country; and [illegible]om the Nobel ceremony in Stockholm, Sweden, he moved directly to the United States. It was not a strange land to Fermi. In 1930 the University of Michigan had invited him to teach at its summer school; and he spent most of his summers thereafter in the United States, where he gained a reputation for the clarity of his lectures at such schools as Columbia University, New York City; the University of Chicago; and Stanford University, Palo Alto, California.

In 1939, then, he moved to New York City and became professor of physics at Columbia. There he continued experiments that he had started in Italy on the nature of uranium fission. At the end of 1941 Fermi and his staff joined the group at the University of Chicago that was absorbed in developing atomic energy. With graphite as the moderator to control the rate of reaction, they built the first controlled, self-sustaining nuclear reactor. The site was a squash court under the stands of the university's unused stadium. Today near the site a plaque states, "On December 2, 1942, man achieved here the first self-sustaining chain reaction and thereby initiated the controlled release of nuclear energy."

In 1922 the Italian physicist Enrico Fermi received his doctorate from the University of Pisa (below), which was founded in 1343 and today includes a branch of the Italian National Institute of Nuclear Physics. After further studies abroad and teaching in his native country, he moved to the United States in 1939 and two years later joined a group at the University of Chicago that was doing research in atomic energy. There, at what had been the squash court under the stands of the university's former stadium, the first controlled self-sustaining nuclear reactor was built; and on December 2, 1942, the first self-sustaining chain reaction took place, thereby initiating the controlled release of nuclear energy. Today a plaque near the site commemorates this event. (Also, see photograph, page 25.)

In 1943 Fermi went to Los Alamos, New Mexico, and worked there on the atomic bomb project until the end of World War II, when he returned to the University of Chicago to continue research on radioactivity. In 1944 he became a citizen of the United States. He served from 1948 to 1950 as an adviser to the U.S. Atomic Energy Commission.

Practically all the awards and honors established for physicists went to Fermi. He was a founder-member of the Royal Academy of Italy and a foreign member of the Royal Society of London.

A year after Fermi died of cancer, the Institute for Nuclear Studies at the University of Chicago was renamed the Enrico Fermi Institute for Nuclear Studies. An artificially produced element (atomic number 100) was named fermium in his honor.

After his death it was discovered that year after year he had given himself the exercise of solving all the problems of the demanding written examinations required of doctoral candidates in physics at the University of Chicago. With characteristic clarity, Fermi had written most of the solutions in a single line.

FERRARIS, GALILEO (1847–1897)

One of the unsung heroes of science is the Italian physicist Galileo Ferraris. He discovered that the application of a rotating magnetic field can produce alternating current for power, and he devised a synchronous motor. At the same time that he was doing this work, however, the Croatian-U.S. scientist Nikola Tesla was making the same discoveries. Tesla obtained U.S. patents on the synchronous, induction, and split-phase motors and is generally credited with their discovery. Ferraris' work was very important to the development of the hydroelectric industry in Italy. (*See* Nikola Tesla.)

In 1878 he completed studies on electromechanics for a conference group considering the industrial applications of

electric light. In that same year he published his theorems on the distribution of constant electricity. He also wrote a paper entitled "On the Different Phases of Electrical Current, on the Retardation of Induction, and on the Dissipation of Energy in the Transformer."

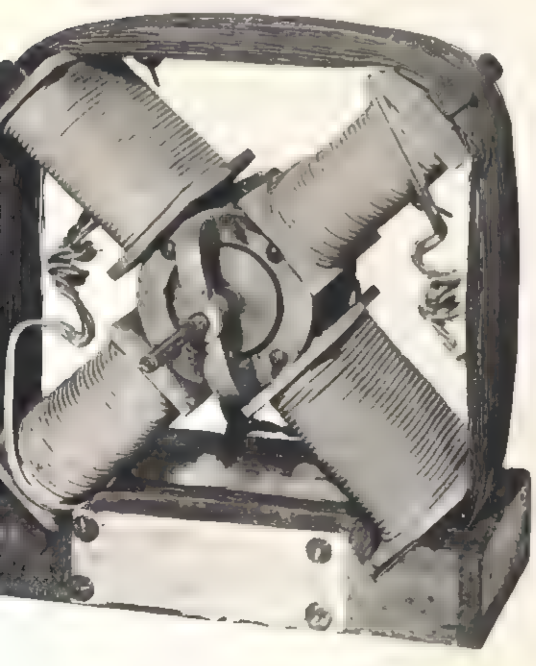
Other papers by Ferraris include "On the Mathematical Theory of the Propagation of Electricity in Homogeneous Bodies" and "On the Employment of an Ordinary Compass to Measure Galvanic Intensity." His interest in simplifying and popularizing the work of the great German scientist Johann Karl Friederich Gauss led to a paper on optical geometry, "On the Cardinal Properties of Dioptical Instruments."

It was 1885 when Ferraris made his synchronous motor, consisting of two coils—one from a galvanometer—and a copper cylinder. A generator was provided with two alternating currents, and the cylinder was suspended in a revolving magnetic field. The cylinder then revolved, providing the basis for the motor.

Ferraris was born in Livorno Ferraris, Vercelli, Italy. He was educated at the Livorno School and received a degree in engineering from the University of Turin. The thesis on teledynamics that he wrote for the degree was later published. After graduation he became an assistant at the Industrial Museum in Turin, and in 1877 he was appointed professor of technical physics at Turin. In 1896 he became a senator. His life was cut short at the age of fifty by a fatal attack of pneumonia.

Galileo Ferraris

Discovering that the application of a rotating magnetic field can produce alternating current for power, the Italian physicist Galileo Ferraris devised a rotating magnetic-field motor to be used as a generator in his synchronous motor of 1885. Two split-phase currents from the inductor of the former produced two magnetic fields at right angles to each other, which together formed one rotating magnetic field.



FEYNMAN, RICHARD PHILLIPS
(1918–)

For his research in quantum electrodynamics conducted during the early 1940s, Richard Phillips Feynman of the California Institute of Technology shared the 1965 Nobel Prize in physics. His co-winners were J. S. Schwinger of Harvard University and Shin'icherō Tomonaga of Tokyo Education University in Japan. The three conducted similar, but independent, research in quantum physics during World War II. (*See* Julian Seymour Schwinger; Shin'icherō Tomonaga.)

Feynman, born in New York City, received his bachelor's degree from Massachusetts Institute of Technology (1939) and a doctorate from Princeton University (1942). While at the latter school, he worked on the early stages of the atomic bomb project in separating uranium isotopes. He also worked in theoretical physics at the Los Alamos Scientific Laboratory in New Mexico and was present at the first atomic bomb explosion at Alamogordo. He later became associate professor in theoretical physics at Cornell University, and after 1951 he held the position of Tolman Professor of Theoretical Physics at the California Institute of Technology, Pasadena. In 1954 he won the Albert Einstein Award for scientific achievement. Among his publications are *Lectures on Physics* (1963–1965).

FIBIGER, JOHANNES ANDREAS GRIB
(1867–1928)

Experiments by the Danish pathologist Johannes Andreas Grib Fibiger early in the twentieth century gave impetus to cancer research. In 1926 he was awarded the Nobel Prize in medicine or physiology for experiments in producing gastric tumors in rats.

Although most of the tumors produced by Fibiger would not meet the modern criteria for fully developed cancer, he provided a method for producing cancer artificially. By supporting the view that cancer can be brought about by external influences, Fibiger's studies also led to important experiments on the long-term effects of irritants.

Fibiger was born in Silkeborg, Denmark. Like his father, he became a physician, qualifying in medicine in 1890. His research and academic posts included the chair of pathological anatomy at Copenhagen University, assumed in 1900. When he began his cancer studies, there already had been some success with transplantation of cancerous tissues, but the method shed no light on the origin of cancer.

Fibiger's studies began when he was examining tuberculous rats and happened to find cancer in the stomach of three. A parasite later named *Gongylonema neoplasticum* was present in the tumors. With perseverance Fibiger traced the parasite to a tropical cockroach that had entered the country in sugar from the West Indies. When the rats at the sugar refinery ate the cockroaches, larvas coiled in the striated muscles of the insects developed into adult nematodes in the stomachs of the rats. Fibiger fed such larva-infected cockroaches to experimental rats and mice and produced malignant tumors, even transplanting one from a mouse. In 1913 he published his results.

Fibiger's methodological research soon encouraged K. Yamagiwa, a Japanese scientist, to produce cancer on the skin of rabbits through repeated applications of coal tar. Fibiger himself helped extend this type of study. Several cancer-causing substances have since been isolated from coal tar.

Fibiger hoped that parasites might be revealed as the cause of some human cancer. No proof has been produced, though some scientists believe that parasites might carry a virus that is a real causative agent.

The metastases (new growths remote from the original tumor) seen in the disease of Fibiger's rats were true metastases in that they resulted from the inherent ability of morbidly overactive cells to establish new centers and multiply and in that they contained no parasites; the cells themselves had become malignant. It was shown later, however, that Fibiger's animals must have been lacking the then unknown vitamin A; for it is now known that a deficiency of this vitamin produces lung lesions similar to those interpreted by Fibiger and his contemporaries as cancer metastases. It was learned also that gastric tumors similar

to those interpreted in Fibiger's time as fully developed cancer occur under vitamin A deficiency in the presence of the *Gongylonema*. Nonetheless, Fibiger's studies have had a lasting influence on cancer research.

FINSEN, NIELS RYBERG (1860–1904)

Toward the end of the last century Niels Finsen, a Danish physician who had become interested in the problem of the biological effects of radiation, succeeded in developing treatments for skin diseases by using light rays of appropriate wavelengths. His work was guided by a subtle ability of interpretation and a profound belief in the therapeutic potentialities of radiation. All this induced him to make experiments that were considered quite absurd and obliged him to face difficulties of all kinds. In 1903, however, he received the Nobel Prize in medicine.

North of Great Britain, in the Atlantic between Iceland and Scotland, lie the Faeroe Islands, or islands of the sheep. There, at Thorshavn, Niels Finsen was born. His parents, who were Icelanders, sent him to school in Reykjavik, the capital of Iceland. It was, however, at Copenhagen University that he took his degree in medicine in 1890 and after another three years became professor of general [illegible].

Because his health had been undermined by an undiagnosed, incurable disease, Finsen was unable to lead a very active life. During the idle reveries in which he often indulged in the pale northern sun, he became aware of the strange reactions of animals to the sun's light and heat. Having noticed that he himself could work better in a well-lighted room, he turned to books for an explanation.

People in those days were just emerging from the period in which those who went swimming in summer covered themselves for protection against the sun's rays, which were considered harmful to the skin. It is not surprising, then, that what Finsen read was not of much use to him. He did, however, take an interest in a report, which would today be branded as quackery, relating how a fourteenth-century English doctor had cured the young son of Edward II of smallpox—a terrible disease not only because it was almost always fatal but also because of the disfigurement that it usually caused—simply by wrapping him in red clothing.

Later writers had recognized the influence of various light rays on the phenomena of metabolism and on the course of certain skin diseases. Finsen went on with his observations, which were sometimes inspired by quite trivial occurrences: a cat's moving out of the shade into the sun convinced him that the sunlight must possess beneficial qualities; the tanning of his own arm showed him the skin's different reactions to the sun's rays, depending on the degree of exposure; examination of a tadpole submitted to the action of a strong ray of light revealed that in such a case the white corpuscles become especially active. All this led him to conclude that the sun's effect on the body can sometimes be beneficial and sometimes harmful.

At his institute in Copenhagen, Niels Finsen spent the last few years of his life trying to perfect his phototherapy methods still further, though he was confined to a wheelchair.

Niels Finsen

In 1893 he developed a treatment for smallpox by red light; that is, a light excluding the actinic rays. Finsen thought that it was precisely the actinic rays that were responsible for the inflammation and consequent infection of the lesions, which, in turn, caused blood poisoning. He tried to convince the chief physician of the Bledgman Hospital in Copenhagen to test this treatment, but in vain; people thought him a visionary, and, considering the mentality of the times, they could hardly be blamed.

Luckily, though, two Norwegian doctors read his report and conducted the experimental treatment on a number of smallpox sufferers in their country. After two weeks in a room lighted by a faint red light, in which the sun could not enter, the patients were cured and had no pockmarks. Treatment of patients in Sweden proved equally successful, and Finsen became unexpectedly famous.

Finsen was still viewed with distrust, however, when shortly afterward he tried to prove the therapeutic virtues and bactericidal properties of those same rays that were detrimental to smallpox. Finsen had not merely observed the phenomena but had also established that the effect of the radiation was based on the kind of tissue exposed to it. He observed that the same rays were harmful in some cases and beneficial in others.

He believed that ultraviolet rays could cure those suffering from another obstinate disease, lupus vulgaris, a tuberculous disease in which the bacilli inexorably turn the victim's face into a horrible sore. He did not lose heart at his colleagues' incredulity and in his search for a light source strong enough to take the place of the light of the sun, which is very weak during the long Danish winters, turned to Winfeld Hansen, the chief engineer at the Copenhagen power plant.

Filled with admiration for Finsen's idea, or perhaps knowing too little about medicine to fully understand its nature and consequences, Hansen constructed an arc lamp so strong that it could act faster than sunlight in killing the bacteria that, in the case of tuberculosis

of the skin, are very near the surface of the skin. In November 1895 Finsen was thus able to start experimenting with this new treatment on the face of an incurable sufferer. After an inauspicious beginning Finsen was finally able to note an improvement: the ulcerous skin first became inflamed and then scaled off, revealing healthy new skin underneath. By the following spring the patient's appearance had returned to normal, and this induced two industrialists to found the Light Institute, where Finsen was free to apply his phototherapy method.

Finsen must have felt happy at last, though he had many serious personal troubles, chief of which was the progressive worsening of his incurable illness. He was also afflicted with pneumonia and dropsy, which wore out his already weak body. All this, however, had only the effect of spurring him on—his activity became feverish precisely because he had a presentiment that he had little time left.

Disappointed by certain results that, after all his efforts, seemed to him much slower and poorer than the original experiments had seemed to promise, Finsen decided to use increasingly strong arc lamps and to concentrate the rays through quartz, not glass, lenses, since this would double the power, and therefore the effectiveness, of the rays. The heat became unbearable, though, and Finsen improved his lamps still further by the addition of water filters that separated from the ultraviolet rays most of the infrared ones, which are useless and harmful and which electric arcs produce in great quantity.

Within a few years a new institute was built in Copenhagen. It was crowded with patients who were full of hope and doctors who wanted to learn the miraculous therapy of the emaciated Finsen, who, sustained by his dauntless willpower, directed his hospital from the wheelchair to which he was confined.

Finsen carried on his research until his death, well aware that there was still much to be done. The basic outlines of his studies are contained in his work *On the Employment in Medicine of Concentrated Chemical Light Rays* (1896).

FISCHER, EMIL HERMANN (1852–1919)

Studies by the German organic chemist Emil H. Fischer on the sugar and purine groups of substances were recognized in 1902 with the Nobel Prize in chemistry. Fischer was the prime investigator in both areas, and later he helped lay the foundation for research into protein structure.

Fischer was born in Euskirchen, Rhenish Prussia. He finished high school in Bonn at the head of his class. In 1874 he obtained his doctorate from the University of Strasbourg. Fischer was appointed professor successively at Erlangen (1882), Würzburg (1885), and Berlin (1892). Under his direction the laboratory at Berlin became one of the world's greatest, attracting a stream of brilliant students.

Emil Fischer

In 1875 Fischer published his discovery of the organic derivatives of hydrazine, a compound of nitrogen and hydrogen. This discovery opened the way for solving complex problems of carbohydrate chemistry. Fischer later discovered that phenylhydrazine forms well-defined crystalline derivatives with sugars, making it possible to separate the sugars from syrups. He then proceeded to isolate and to study the structures of sugars. This study involved the properties and reactions of substances that cause fermentation; thus, Fischer was instrumental in beginning enzyme chemistry.

Nearly all the facts about the purine group, which he named, are attributable to Fischer. He established the formulas of uric acid, caffeine, xanthine, and other compounds of the purine group and eventually synthesized purine itself. The work had far-reaching implications because purines later were found to be an important part of the nucleic acids group —key molecules of life.

At the time Fischer received the Nobel Prize, he had turned to the problems of protein structure and synthesis. He was able to show how amino acids combine within the protein molecule, and he built a protein molecule of eighteen amino acid units.

All the important scientific societies of the world recognized the merit of Fischer's researches, which are considered to be unparalleled in the history of organic chemistry. In 1890 he was awarded the Davy Medal of the Royal Society of London, of which he was elected a foreign member in 1899.

FISCHER, HANS (1881–1945)

The German biochem[illegible] Hans Fischer was awarded the 193[illegible] Nobel Prize in chemistry for his studi[illegible] the makeup of hemin and chlorop[illegible] and for his synthesis of hemin. A [illegible]lline product of hemoglobin, hemi[illegible] part of the blood's dyestuff. Fisch[illegible]ook bilirubin, a bile pigment, and [illegible] molecule in half. From this he go[illegible]ew acid that contained a section o[illegible] hemin molecule. He was, therefo[illegible] to study the structure of the hemin [illegible]cule in detail and determine how t[illegible]ed with the synthesis.

One of his discoveri[illegible]s that hemin and chlorophyll have [illegible]mmon structure. (As hemin makes [illegible]l red, chlorophyll makes plants g[illegible] The chlorophyll molecule contains [illegible]gnesium at its center; in the hemin m[illegible]cule the same position is occupied b[illegible]

Fischer was born in [illegible]hst, Germany. He received a docto[illegible] in chemistry from the University o[illegible]burg in 1904 and a doctorate in [illegible]ne from the University of Munich [illegible]908. After a period of practicing m[illegible]ne, he began to perform chemical r[illegible]h under the supervision of Emil Fi[illegible] no relation) in Berlin. In 1916 he wa[illegible]ed professor of medical chemistry [illegible]sbruck and five years later becam[illegible] professor of organic chemistry at M[illegible] and director of the Institute for Orga[illegible]hemistry at the technical high schoo[illegible]orld War II air raids on Munich de[illegible]oyed his laboratory, and he committ[illegible] suicide.

FLEMING, SIR ALEXANDER (1881–1955)

A fortunate accident and a sharp eye resulted in discovery of the lifesaving antibiotic penicillin by the Scottish bacteriologist Alexander Fleming. For his achievement Fleming shared the 1945 Nobel Prize in medicine or physiology with E. B. Chain and Sir H. W. Florey. (*See* Ernst Boris Chain; Sir Howard Walter Florey.)

Fleming was born in Ayrshire, Scotland, and was educated at Kilmarnock Academy in his native country. After graduation he worked as a shipping clerk in London for five years before earning a scholarship that enabled him to enroll at St. Mary's Hospital Medical School, University of London. Upon completion of his studies there, he stayed to do research under the direction of Sir Almroth Wright, a pioneer in vaccine therapy.

As a captain in the Army Medical Corps during World War I, Fleming was

sent to a rese[illegible]h center that Wright had started in [illegible]ance. Under difficult conditions and [illegible]ith scanty equipment, the scientists [illegible]gled against gas gangrenes, the e[illegible]nic of Spanish influenza in 191[illegible]d septicemia caused by wound inf[illegible] The usual antiseptics were pro[illegible]adequate.

In 1921 Fl[illegible] was named assistant director of St[illegible] Hospital. Resuming his research [illegible]e aim of finding antibacterial sub[illegible] that would combat infections wi[illegible]arming animal tissue, he prepared [illegible]nite number of bacterial culture[illegible] these gave negative results in mo[illegible]s. In 1922, however, he discovere[illegible]zyme, a protein that destroys bac[illegible]

It was Fle[illegible] practice to save any culture until [illegible]as certain of all reactions. The sy[illegible]tic disorder of his laboratory led t[illegible] epochal discovery of penicillin in [illegible]. When the cultures were left to d[illegible]p undisturbed for long periods, the[illegible]ld easily be polluted by germs in [illegible]icinity. In the case of penicillin, t[illegible] something different was involve[illegible]old invaded a liquid culture and [illegible] the bacteria that had been thrivin[illegible].

Fleming [illegible]out to discard the old culture wh[illegible] noticed the startling phenomeno[illegible]began to cultivate the mold and g[illegible]ame results every time the mold was transplanted into cultures of pathogenic germs. The mold, which was soon identified as *Penicillium notatum*, liberated a substance that arrested the development of many disease-causing agents and yet did not seem harmful to humans. Fleming named the compound penicillin. He experimented with its effect on white blood cells and determined that it did not harm them even at concentrations highly noxious to bacteria.

At St. Mary[illegible]tal in London, England, Alexander Fl[illegible] worked as a brilliant and persevering [illegible]her. It was there that in 1928 he mad[illegible]lmost chance discovery of the extraord[illegible]ntibiotic penicillin.

Being no chemist, Fleming could not isolate the substance. His announcement of the discovery aroused little interest. The coming of World War II, however, intensified the need for antibacterials; and in 1939 the scientists Howard Florey and Ernst Chain, who were working at Oxford University, found a way to extract, concentrate, and purify penicillin.

At first the precious mold was cultivated in a number of small containers, but soon the great demand made a faster system necessary. Efforts in both Great Britain and the United States succeeded. In 1941 Fleming visited the United States to help set up mass production. Penicillin was first used for war casualties in 1943 and proved to be highly effective.

Fleming became sought after and widely honored. He was made a member of the Royal Society in 1943 and was knighted in 1944.

FLOREY, SIR HOWARD WALTER
(1898–1968)

A pioneer in the development of penicillin, Sir Howard Walter Florey shared the 1945 Nobel Prize in medicine or physiology with his colleague E. B. Chain and with Sir Alexander Fleming. Florey and Chain isolated the antibacterial agent from *Penicillium notatum*, the mold that Fleming had discovered killing staphylococcus germs in a laboratory culture. (*See* Ernst Boris Chain; Sir Alexander Fleming.)

Florey, who was born in Adelaide, Australia, received his medical education at the University of Adelaide and at Oxford University in England, where he studied as a Rhodes scholar. For a time he did research in Great Britain and in the United States and then, from 1927 to 1931, held a fellowship and lectureship at Cambridge University. He was professor of pathology at the University of Sheffield from 1931 to 1935 and at Oxford from 1935 until 1962, when he became provost of Queen's College, Oxford.

Early in his career Florey was drawn to the aspects of inflammation and also to an investigation of the ways in which mucous-membrane secretions prevent bacterial infection of the respiratory and gastrointestinal tracts. In the course of his work, he became interested in lysozyme, which Fleming had discovered in 1922. The enzyme, found in tears, saliva, and mucus, dissolves certain bacteria.

Sir Howard Florey

Florey planned a major survey of antibacterial substances that occur in nature—plant extracts and products of fungi and bacteria themselves. Penicillin, product of a fungus, showed so much promise that Florey concentrated on investigating it and producing it for clinical use. In 1943 he went with a research team to North Africa to investigate the possibility of treating war casualties with penicillin. It proved to be dramatically effective.

Later, Florey concentrated on atherosclerosis, a disease of the blood vessels that is a factor in coronary thrombosis and cerebral accident, or stroke. He broadened the scope for investigation of the puzzling ailment when he found that domestic pigs develop a similar condition.

Florey was made a fellow of the Royal Society in 1941 and its president in 1960. Three years later he was elected a foreign associate of the U.S. National Academy of Sciences. In recognition of his work with penicillin, he was knighted in 1944 and given a life peerage and the Order of Merit in 1965.

FORD, HENRY (1863–1947)

The U.S. industrialist Henry Ford was the father of modern mass production. In 1913 he introduced an innovation that was to have a profound effect on industry everywhere: the assembly line, a system whereby automobile parts were assembled as they moved along a line from worker to worker until the finished car emerged at the end.

Ford's Model T was the first car designed for a mass market: it was within the economic reach of the average person. The social changes brought about

by the widespread use of the automobile were great; one biographer commented that Ford changed the whole "American way of life." From 1908 to 1927 more than 15 million Model Ts came off the assembly line and were sold.

Henry Ford

Having made a successful product, Ford was reluctant to change it. He insisted on mechanical brakes rather than hydraulic brakes. He continued to use the four-cylinder engine rather than those with six or eight cylinders. He produced the Model T in only one color, black. In 1927, however, realizing the need for change, he retooled completely and made an all new car, the Model A. He retooled again in 1932 for the V-8. In the meantime, however, he had lost his sales lead to the General Motors Corporation.

Ford was born on a farm near Dearborn, Michigan. He attended school only to the age of fifteen. Being interested in mechanical things, he became apprenticed to a machinist and later worked for an electric light company as an engineer. In 1893 he built his first automobile and six years later founded the Ford Motor Company. Even after he was the head of an industrial empire, Ford delighted in tinkering with watches and joining in repair jobs.

When he became rich and successful, he also became a philanthropist. He was interested in many things, some of them seemingly contradictory. His company was a major producer of war materials in World Wars I and II; yet he also financed an expedition of pacifists seeking an early end to World War I.

FORSSMANN, WERNER THEODOR OTTO (1904–)

A daring experiment involving his own heart led to a Nobel award for the German surgeon Werner Theodor Otto Forssmann. Together with two other pioneers in heart research—André F. Cournand and Dickinson W. Richards—Forssmann won the 1956 Nobel Prize in medicine or physiology. They developed cardiac catheterization, which improved diagnoses of heart ailments. (*See* André Frédéric Cournand; Dickinson Woodruff Richards.)

Forssmann's contribution to the technique began when he opened a vein in his arm, inserted a catheter until it reached his heart, and then had an x-ray photograph made of his chest. His experiment showed the feasibility of investigating the structure and function of the heart by passing into it a catheter that is opaque to x-rays.

Forssmann was born in Berlin, Germany, and studied medicine at Berlin University. During World War II he served at the front and later was chief surgeon at a military hospital for the seriously wounded. In 1950 Forssmann was appointed chief surgeon of the urological department of a hospital at Bad Kreuznach and in 1957 became chief surgeon of the Evangelical Hospital at Düsseldorf.

He served as professor of surgery at the University of Mainz; the University of Cordoba, Spain; and the University of Düsseldorf. In 1954 the German Academic Societies awarded him the Leibniz Medal.

FOURIER, JEAN BAPTISTE JOSEPH (1768–1830)

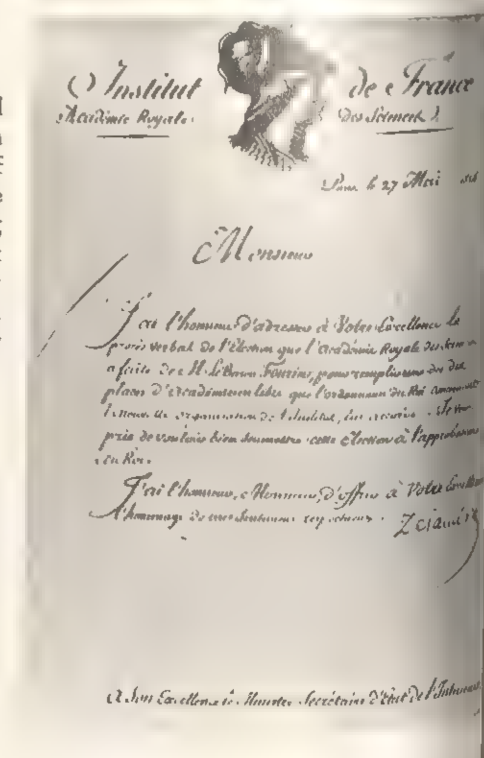
The bishop of Auxerre, France, moved to pity by the sad fate of a tailor's son who had been orphaned at the age of eight, entrusted the young boy to the care of a charitable lady, little knowing what his future career would be. At that time the child was already exceptionally winning in his ways and fascinating in his talk. At the age of twelve, after studying for some time in Paris, he was sent to the military academy in Auxerre, which was then run by Benedictines. His character, however, had by this time taken a difficult and violent turn. He was a stubborn and undisciplined pupil but still retained his exceptional qualities. Although he had a great gift for writing, which he used to win the sympathy of his teachers, composing magnificent sermons for them, he soon realized that the study of mathematics was his destined road and embarked on it with all his energies. Actually, he had dreamed of a military career, but this was closed to him because of his low birth.

His first original research in mathematics led to the theory of algebraic equations and their numerical solution. He presented it in 1789, at the age of twenty-one, to the Paris Academy of Sciences, where it was well received.

Meanwhile, he had joined the revolutionary cause, but he was soon alarmed by the excesses of the Terror, particularly those that victimized intellectuals. Then Napoleon, on his accession to power, surrounded himself with outstanding scholars; and in 1795 Fourier, who was already known for his brilliant studies, was appointed as teacher at the newly founded École Normale in Paris. He threw himself into teaching with the greatest success, going back to the sources of mathematical discoveries, illustrating the mental process followed by the various discoverers, and always managing to achieve a happy fusion between theoretical exposition and practical application. His courses were followed with keen interest at the École Normale and later at the École Polytechnique.

What had hitherto been the quiet life of a worthy university teacher, absorbed in his scholarly research, was suddenly filled with adventure, conquests, and passion. When in 1798 Napoleon left for

In a letter dated May 27, 1817 the French astronomer Jean Baptiste Delambre announced the election of Jean Baptiste Fourier to membership in the French Academy of Sciences.


Institut de France
Académie Royale des Sciences

Paris le 27 Mai

Monsieur

J'ai l'honneur d'adresser à Votre Excellence le procès verbal de l'élection que l'Académie Royale des Sciences a faite de M. le Baron Fourier, pour remplir une des places d'académiciens libres ...

J'ai l'honneur ...

A Son Excellence le Ministre Secrétaire d'Etat de l'Intérieur

Jean Baptiste Fourier

his Egyptian campaign, intent on bringing progress and culture to that country, he took with him various men of science to form the so-called Legion of Culture, and among them was Fourier. In the new Egyptian Institute they zealously started to teach the sciences to slow-witted and rebellious natives, who were longing only for the moment when the invaders would leave. The expedition was a military failure, but Fourier remained for three years as governor of lower Egypt, carrying out his numerous political, administrative, and scientific functions with undiminished zeal, despite his disillusionment.

When he returned to France, he was appointed prefect of the department of Isère, with headquarters in Grenoble. The region was difficult to administer because of widespread unrest; but Fourier, who had meanwhile been made a baron, used his diplomatic gifts to overcome the various problems.

During this time he did not neglect his research. In 1804 he wrote a treatise summing up his studies on numerical equations, *Analyse des équations déterminées.* He also started work on his *Théorie analytique de la chaleur.* He presented the preliminary treatise to the Academy of France in 1807 and was awarded its prize in 1812. Fourier fully deserved this honor: the mathematical method presented in the treatise, to which he had devoted the best of his fertile invention, was sufficient to immortalize him. Curiously enough, the three members of the commission, whose task was to choose the most deserving candidate for the prize, were not wholly convinced of the perfection of the mathematical form of the theory presented by Fourier. In their opinion the premises were not sufficiently valid; something more was needed, and they therefore awarded him the prize with reservations. This attitude infuriated Fourier, who was well aware of the importance of his work. In reality, however, the commission was not wrong; something was missing in Fourier's theory that was to be supplied only a hundred years later with the Lebesgue integral. Fourier was too sure of his intuition in physics and geometry to waver in the face of a difficulty that he realized would not be resolved until sometime in the distant future, since the notion of integral was as yet insufficiently developed. Not only did he disregard the criticisms but also counterattacked by affirming that pure mathematicians should not dabble in mathematical physics. In 1822 he published his work without modifying it in any way.

The mathematical methods that he devised allowed him to accurately determine the properties of heat conduction. These methods, however, were applicable to more than heat phenomena and proved useful in the discovery of periodic factors in phenomena that appeared to be completely aperiodic. Today they are applied in astronomy, geophysics, electronics, engineering, acoustics, and all problems involving the study of vibrations.

Fourier's decline coincided with that of Napoleon. When Napoleon was sent to Elba, the favor of the Bourbons enabled Fourier to keep his post in Grenoble. On hearing of the emperor's escape to the mainland, he went posthaste to Paris to warn his new masters, to whom he had taken an oath of loyalty. By a stroke of irony they did not believe him; but when he returned to Grenoble, he found himself face-to-face with Napoleon, who had captured the city. The emperor took him prisoner; however, remembering their old friendship and the closeness of their association during the Egyptian campaign, Napoleon made peace with him.

This was the beginning of the end. Fourier had foreseen that Napoleon's decline was imminent, but this time he did not abandon him. At the second Restoration the Bourbons showed themselves hostile to Fourier, who had to flee and was even obliged to pawn his possessions to make ends meet. Through the influence of old friends, however, he was appointed director of the Seine Institute of Statistics, thus finding a new source of income on which to live. Because of the opposition of the Bourbons to his election to the Academy of Sciences in 1816, it was not until 1822 that the persistent efforts of some of the members prevailed and he was elected secretary for life. Time, however, had impaired his old capacities, and he did little of value during his remaining eight years.

FRANCK, JAMES (1882–1964)

The 1925 Nobel Prize in physics was awarded to the German-born physicists James Franck and Gustav Hertz for their studies of the changes of energy that occur when atoms and electrons collide. By bombarding gases with electrons of different energy levels, they showed that an electron needs a certain minimum energy level to ionize an atom. This tended to prove one of Niels Bohr's theories about the atom: that it can take up energy only in such discrete amounts as will transform that energy from one state to another. (*See* Gustav Hertz.)

Franck was born in Hamburg, Germany, and studied at the universities of Heidelberg and Berlin, receiving his doctorate in physics from the latter school in 1906. He fought for Germany in World War I and was decorated with the Iron Cross for his services.

In 1920 he became a professor of physics at Göttingen. It was there that he and Hertz performed their prizewinning studies. Because of the Nazi government, he resigned his post in 1933 and emigrated to the United States. Upon his arrival in 1935, he became a professor at Johns Hopkins University, Baltimore, Maryland, and in 1938 was appointed professor of physical chemistry at the University of Chicago. Eventually he became a naturalized citizen of the United States.

Although he worked on the atomic bomb project during World War II, he was strongly opposed to dropping the bomb on Japan. In 1945 he was one of a group of scientists who unsuccessfully petitioned the secretary of war to prevent the use of the bomb.

FRANK, ILYA MIKHAILOVICH (1908–   )

For his explanation of the Cherenkov effect—the light emitted by charged particles traveling at very high speeds—the Soviet physicist Ilya Mikhailovich Frank was awarded the 1958 Nobel Prize in physics. He shared the prize with Pavel A. Cherenkov and Igor E. Tamm. Cherenkov made the discovery that bears his name in 1934, and Frank and Tamm provided detailed theoretical explanations of it in 1937. (*See* Igor Pavel Alekseevich Cherenkov; Evgenyevich Tamm.)

Cherenkov propelled high-energy particles through a medium at a speed greater than the speed of light in that medium. He was able to detect the trail of light waves, or radiation, left by the particles under these conditions—thus the Cherenkov effect. The waves are called Cherenkov radiation. (*See* Pavel Alekseevich Cherenkov.)

Frank, the son of a mathematics pro-

fessor, was born in St. Petersburg (now Leningrad), Russia. He graduated in physics from Moscow State University in 1930 and five years later received the prestigious degree of doctor of physical-mathematical sciences.

In 1934 Frank left the State Optical Institute in Leningrad, where his working career had started three years earlier, and went to do research at the Lebedev Institute of Physics of the Academy of Sciences of the U.S.S.R. It was there that he worked with Cherenkov and Tamm. He was placed in charge of the atomic nucleus laboratory at the institute in 1941, and in 1944 became a professor at Moscow State University.

For their joint discoveries Cherenkov, Frank, and Tamm were awarded the Stalin Prize in 1946. Frank was elected a member of the Academy of Sciences of the U.S.S.R. in the same year.

FRANKLIN, BENJAMIN (1706–1790)

Printer, publisher, inventor, public servant, diplomat, and scientist, Benjamin Franklin was one of the most prominent and greatly admired men of the eighteenth century. Franklin's greatest achievements were in the field of public service, though his experiments with electricity were the accomplishments that first brought him worldwide fame.

Franklin was born in Boston, Massachusetts, the fifteenth child of Josiah Franklin, a candlemaker who had emigrated to the United States from England. Young Franklin studied first under the guidance of his father, then with an uncle, and later with a private tutor. At the age of twelve he became a printer's apprentice in his brother James's printshop. After a bitter quarrel with his brother he left Boston and went to New York City. Finding no work there, he went to Philadelphia, where he quickly got a job in a printing establishment. A short time later he returned to Boston but soon was on his way to London, England, to buy printing equipment. He stayed there several years, working for a printer. On his return to Philadelphia he set up his own printing business and in 1729 became owner of *The Pennsylvania Gazette*.

During the next twenty years Franklin was very successful in the printing business, as well as in publishing and writing. His life and his writings were characterized by traits for which he remains famous: industry, thrift, temperance, and common sense.

In 1732 Franklin published a unique periodical, *Poor Richard's Almanack*, a kind of calendar that contained simple astronomical illustrations, proverbs, advice, anecdotes, and odd stories. The simple humor and practicality of the publication made it extremely popular, and it sold thousands of copies, a great publishing feat for that time.

Although Franklin was a successful businessman, he had time for intellectual and cultural pursuits as well. Always interested in improving his mind, he learned to read French, Spanish, Italian, and Latin and began to study science, a subject in which he had shown some interest while in England. In 1727 he formed the Junto, a discussion group devoted to politics, morals, and natural philosophy. This led in 1731 to the establishment of the Library Company, the first public circulating library of the colonies. Another outgrowth of the Junto was the American Philosophical Society, which was organized in 1743 to promote scientific studies in the colonies. Eight years later he was instrumental in founding the Academy of Philadelphia, which became the University of Pennsylvania.

There was also time for scientific experiments, and in 1740 Franklin invented a heating device, a type of fireplace, which came to be known as the Franklin stove. Franklin never patented this device, saying he was more interested in sharing it for the common good of everyone than he was in making money from it. From the earliest days of the Junto, Franklin had been assembling data that enabled him to produce theories on the origin and direction of storms. He later made original observations about the causes and structure of cyclones and studied the nature and origin of the Gulf Stream. His scientific activities also extended into such fields as heat and optics. In the latter field he produced an application that was to last through the centuries—the bifocal lens for eyeglasses.

His most important research, however, was in electricity, especially in electrostatics, which was then not widely studied. A particularly controversial point centered around the nature of electricity, which was classified as vitreous if thought to be produced by glass and resinous if thought to be produced by such substances as sealing wax. Fascinated by the electrical experiments with the recently devised Leyden jar (1746), Franklin obtained an electrostatic tube from an English friend and conducted experiments of his own. These led to the theory that an electric substance, or rather an electric fluid, as he called it, is contained in bodies in a definite quantity. This substance may vary under certain conditions: if it increases, the body becomes electrically charged, and the charge is called positive; if the charge decreases, it is called negative. This theory contains some of the same principles as the modern theory of an electron gas.

In 1750 Franklin proved that lightning is electrical in nature. He was not the first to make such an identification, but his kite experiment was the first proof. Franklin attached a key to a kite string and flew it during a thunderstorm. Electrical sparks were produced from the key, thus identifying lightning as an electric

By attaching a key to a kite and flying it during a thunderstorm, Benjamin Franklin established the electric nature of lightning. This led to his invention of the lightning rod.

discharge. This gave him the idea for developing the lightning rod, a device still in use today for protecting structures from lightning during thunderstorms.

Franklin wrote about his discoveries in a work entit..ed *Experiments and Observations o.. Electricity* (1751). This eighty-pa.. ..ook brought Franklin worldwide fa.. ..d is considered to be the first scien.. ..work contributed by an eighteenth .. ..ry American.

For his sci.. .. work Franklin received honora.. ..grees from Harvard, Yale, William .. ..lary, Edinburgh, and Oxford univer.. He also held memberships in sci.. .. societies throughout Europe.

After 1753 ..lin's attentions were more toward ..cs than science. Because he was .. ..pular, a public career was natural. .. ..ook an active part in the events rel.. ..o the American Revolution and w.. ..drafter and signer of both the De.. ..tion of Independence and the U.S. .. ..titution. His last act as a public serv.. ..was the signing of an appeal to Co.. ..s for the quick abolition of slave..

Franklin di.. ..n Philadelphia at the age of eight.. ..r. His posthumously published *Au.. ..graphy* is widely read.

FREUD, SIGM.. (1856–1939)

The found.. ..l greatest exponent of psychoanalys.. ..igmund Freud, was probably th.. ..radical and controversial figure of .. ..ime, though highly influential. Fr.. ..n thought divides the mind into th.. ..go, and superego, with special emph.. ..on infantile sexuality as a motivating ..tor in human behavior.

Freud was ..rn in Freiberg, Moravia (now Pribor, ..echoslovakia), the son of a Jewish merchant. He was already an uncle at birth, a paradoxical situation that was to prove hard for him to overcome. (His father had had two children by a previous marriage.) He attributed his emotional and sentimental temperament to his mother, a lively, gay, and intelligent woman. Of her six children, Sigmund, or "Sigi," the firstborn, was her favorite. Freud returned her partiality with a passionate adoration, which he was later to see as a typical example of the Oedipus complex.

After the Austro-Italian War of 1859, Freud's family moved to Vienna, where he received all his education, first under his father's guidance and then at elementary school and high school. At the age of seventeen he decided to study medicine and entered the University of Vienna, where he worked in the laboratory of Ernst Wilhelm von Brücke. He graduated in 1881 and after military service returned to his work in the laboratory; but in 1883, to earn more money, he took a job in a private psychiatric nursing home. He knew Vienna had a shortage of doctors specializing in nervous diseases, and, seeing the monetary opportunities, he began to concentrate his efforts in this area.

In 1884 Freud published *The Structure of the Elements of the Nervous System*, which stressed the morphological and physiological unity of the nerve fibers and cells. This work won him an appointment as privatdocent (1885) and a grant that enabled him to go to Paris to attend the lectures of Jean Martin Charcot, a famous French neurologist, who impressed Freud with his theories, especially the ones on hysteria.

Freud returned to Vienna in 1886 and entered private practice as a neurologist. That same year he married Martha Bernays, a young woman whom he had met when he was just out of the university and who had inspired him to seek the financial rewards then available in medicine. They had six children, one of whom, Anna, also became a psychoanalyst.

At first Freud used hypnosis in treating patients with mental disorders. He believed that a person's desires or painful experiences might be repressed, or stored in the unconscious, and thus cause behavior that seems unmotivated. Once these desires or experiences are revealed by being brought into consciousness through such methods as hypnosis, the person will know what's causing his behavior and how to cope with it. This method had been used successfully earlier by the Viennese physician Josef Breuer in his treatment of a patient suffering from

In what is today a gray stucco house in Pribor, Czechoslovakia, Sigmund Freud, the founder of psychoanalysis, was born to Jewish parents in 1856. For most of his life, however, Freud lived in Vienna. It was there that, after studying at the University of Vienna and for a short time in Paris, he set up private practice as a neurologist and developed his psychological thinking, going from hypnosis to free association and dream analysis.

Sigmund Freud

hysteria. After the patient had relived unpleasant past experiences while under hypnosis, the symptoms disappeared. In 1895 the two men collaborated on the first psychoanalytic work, *Studies in Hysteria.*

Realizing that hypnosis does not have lasting therapeutic effects and is too dependent on the personal relationship between the patient and the physician, Freud replaced it by the method of free association. This allows the patient to talk freely, with little guidance, thereby gradually revealing what under ordinary circumstances would be kept secret even from his own conscious mind. This analysis of the unconscious mind in order to find the cause and motivation of behavior was called psychoanalysis by Freud.

In addition to free association, Freud also considered dream analysis of vital importance in psychoanalysis, and in 1900 he published what is perhaps his most important work, *The Interpretation of Dreams.* Its aim was to show that dreams are the fulfillment of hidden desires and that their apparent content conceals a latent one, the analysis of which allows the psychoanalyst to explore the unconscious.

The most controversial aspect of Freud's psychoanalytic doctrine was its emphasis on the role of sex, especially infantile sexuality, in the development of neuroses, as set forth in his *Three Essays on the Theory of Sexuality* (1905). According to this work, sexual life in man begins, not at puberty, but at birth, culminating at about the fifth year, after which it is inhibited until puberty, the second culmination of its development. It is the first period that has a great bearing on an individual's subsequent mental health, since inhibitions in the development of the libido, or sexual drive, can result in a neurosis. Freud even believed that a child's relations with its parents are basically of a sexual nature. These theories caused much opposition. The general public thought of the essays as "pornographic theories that ought to be done away with." Many scientists also condemned them, going so far as to say that they were of interest, "not to science, but to the vice squad."

Freud's other writings include *Psychopathology of Everyday Life* (1901). This attributes a great significance to all the acts of everyday life that do not achieve an end (losing objects, making mistakes in reading, unexplained causes of forgetfulness), stating that they actually hide impulses and intentions originating from repressed desires.

At the beginning Freud attracted few followers, but in 1909 he was invited by Clark University, Worcester, Massachusetts, to give a series of lectures on psychoanalysis and to receive an honorary degree. From that time, interest grew rapidly. Although the new teachings met with rejection at first, there was a growing movement in favor of psychoanalysis, and by 1926 there were psychoanalytic societies and clinics in many cities.

In 1930 Freud received the Goethe Prize, and in 1936 he was elected to the Royal Society. Then, with the occupation of Austria by the Nazis in 1938, he was forced to flee to England, where he spent the last year of his life.

FULLER, RICHARD BUCKMINSTER (1895–)

The name of Richard Buckminster Fuller, twentieth-century U.S. architect and engineer, is most widely associated with geodesic domes. It is also closely connected, however, with his term *Dymaxion* for the concept of getting maximum performance from a given input; a Dymaxion structure, then, gives the most efficient performance within the available technology.

Fuller's geodesic domes are spheres in which triangular facets composed of light skeletal struts or flat planes replace the arch principle and distribute stresses within the structure itself. The domes can be set directly on the ground as complete structures. One of the most famous was the U.S. pavilion at Expo 67 in Montreal, Canada.

Fuller was born in Milton, Massachusetts. He attended Milton Academy and Harvard University, which expelled him for "continued irresponsibility and lack of interest in the formal curriculum of the college." As a commander of a U.S. Navy crash-boat flotilla in World War I, Fuller invented a combination of mast, boom, and grappling device to lift downed seaplanes from the water in time to save the pilots who were strapped inside. In appreciation he was awarded an appointment to the U.S. Naval Academy, Annapolis, Maryland.

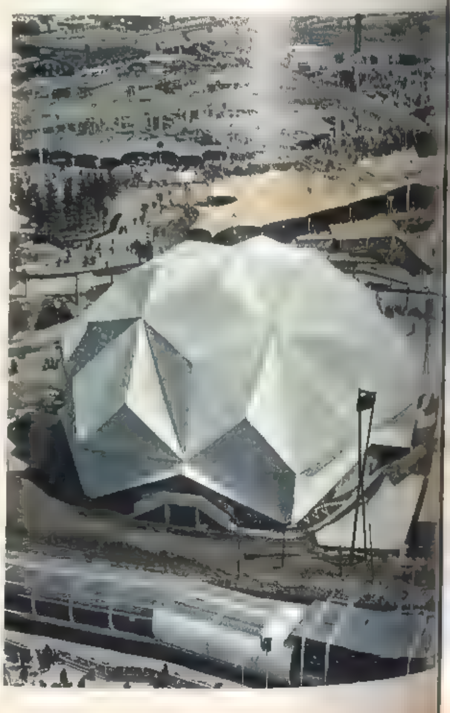
While he was in the navy, Fuller married Anne Hewlett, a daughter of James Munroe Hewlett, architect and muralist. After the war Fuller and Hewlett founded a company that manufactured fibrous building blocks. The death of a four-year-old daughter and serious financial reverses brought Fuller to a time of personal crisis in the early 1920s. It was then that he set as his goal "technological humanism"—a plan to convert the world's resources to human advantage. He urged architectural students to promote the comprehensive use of total technology for the total population at the maximum feasible rate of acceleration.

Fuller held more than 150 patents in more than fifty-five countries. His inventions included a map projection system; low-cost, ready-to-use houses delivered by air; maximum-function, minimum-cost die-stamped bathrooms; and automobiles that could go 125 miles per hour at 28 miles per gallon of gasoline, turn complete circles within their own length, move sideways, and cross open fields. The automobiles were prototypes of a projected omnidirectional air-flotation vehicle that could be used to deliver houses anywhere.

The geodesic dome, however, has been Fuller's greatest success. (*Geodesic* is the mathematical term that refers to the portion of a curve or line that is the short-

R. Buckminster Fuller

Today examples of R. Buckminster Fuller's geodesic domes can be seen in all parts of the world, as the pavilion of the Pepsi-Cola Company at Expo 70 in Osaka, Japan.

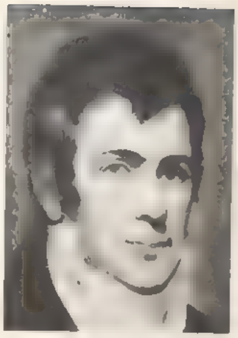


est path between two points on a given surface; on a sphere, the geodesic line between two points is the minor arc of the great circle passing through the two points.) Fuller patented his basic geodesic dome in [illegible]. Buildings based on the design ar[illegible]d for various purposes in all parts of [illegible]orld.

Fuller was [illegible]rded a score of honorary degrees. At Harvard's request he returned there [illegible] 1961 as Charles Eliot Norton Profe[illegible] of Poetry, another of his interests.

Among F[illegible]ublications are *Education Auto[illegible] Freeing the Scholar to Return t[illegible]tudies* (1962); *Ideas and Integrit[illegible]*[illegible]63); *Nine Chains to the Moon* ([illegible] *No More Secondhand God and Othe[illegible]tings*, prose and prose-poem essays [illegible]963); and *Operating Manual for S[illegible]ship Earth* (1969).

FULTON, RO[illegible] 1765–1815)



Robert Fulton

When Ro[illegible]lton was fifteen years old—long b[illegible] thought of developing the stea[illegible] he designed a paddle-wheel vess[illegible]inate poling a boat on fishing trip[illegible] friends. His mechanical aptitud[illegible]t work also in the sky-rocket he i[illegible] in his teens for Independence D[illegible]elebrations. He was a jeweler's ap[illegible]ice and a rather successful port[illegible]inter, however, before he turned to [illegible]ineering.

Fulton, w[illegible]as born on a farm near Lancaster, [illegible]ylvania, went to England in 1786 to study art with Benjamin West, a former Pennsylvanian. The change in his principal interests was reflected ten years later in his *Treatise on the Improvement of Canal Navigation.* While in London, Fulton patented several inventions, including a flax-spinning machine, a machine for making ropes, and a marble cutter and polisher. Chiefly, though, he worked on developing a new system for building canals, but his attempts to interest the United States and France in his proposals failed.

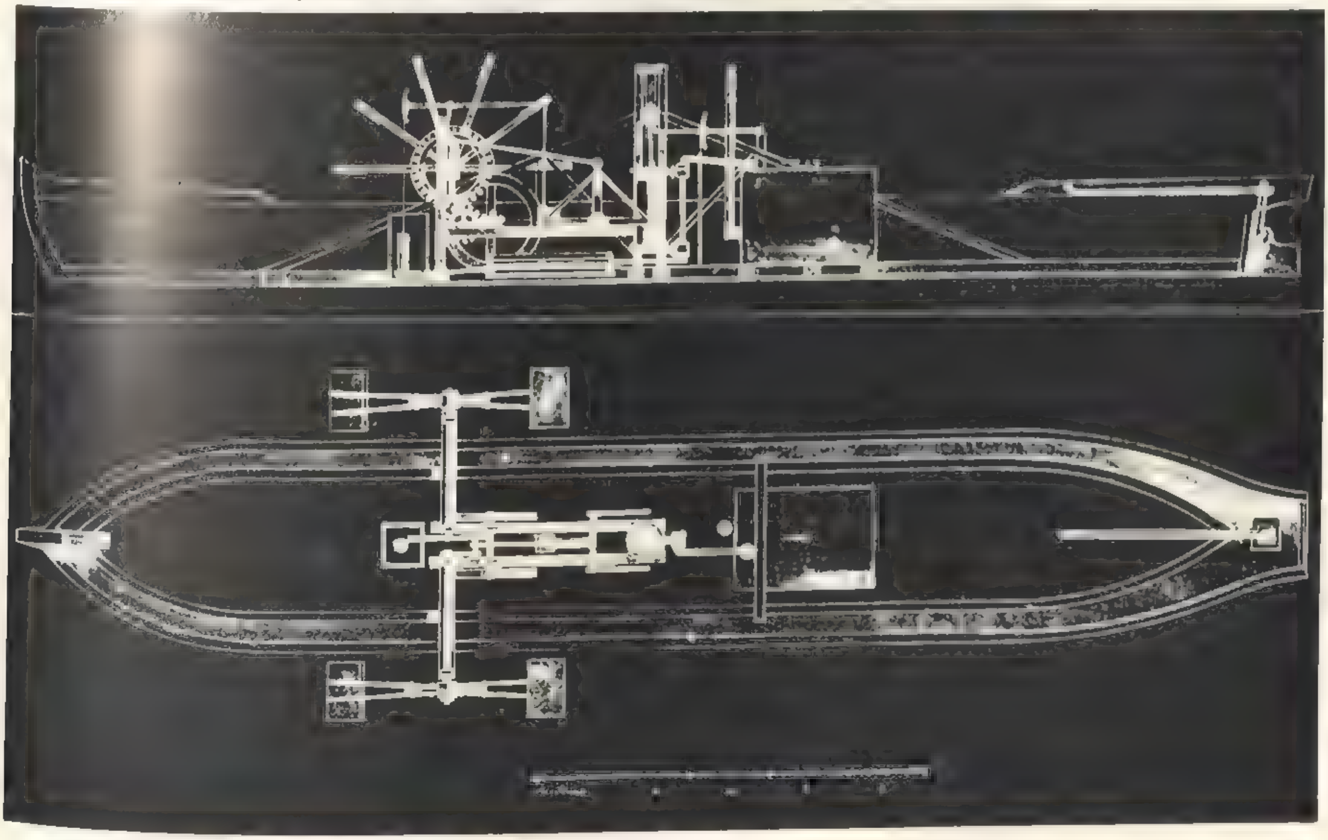
In 1797 Fulton moved to France. In Paris he developed the *Nautilus*, an underwater boat that could shoot torpedoes. He suggested to the French that such a submarine could destroy British warships, but he was unable to interest the French or anyone else in the project. Fulton then turned to steamboats, having formed a partnership with Robert R. Livingston, U.S. minister to France, who had experimented with steamboats and held a monopoly for steam navigation on the Hudson River in New York. A steamboat of Fulton's design was launched on the river Seine in 1803.

After nearly twenty years abroad, Fulton returned to the United States in 1806. Livingston was back also, and soon the two men ordered a boat hull. In August 1807 Fulton's steamboat made the 150-mile trip from New York City to Albany, moving against current and wind without sail or oar. In the fall, commercial schedules were set for *The North River Steamboat*, as it was then called. The following year, after being rebuilt and lengthened to 149 feet, it was registered as *The North River Steamboat of Clermont* and became popularly known as the *Clermont*.

Fulton established an engine works in New Jersey and built steam ferries for the Hudson and East rivers. The Fulton-designed *New Orleans*, which was built in Pittsburgh, Pennsylvania, opened steam navigation of the central U.S. waterways in 1811 when it sailed down the Mississippi River.

The first steam warship was built by Fulton for the defense of New York Harbor in the War of 1812. It was launched shortly before the war ended in December 1814.

The first ste[illegible] designed by Robert Fulton was launched on the river Seine in 1803 by him and his partner, Robert R. Livingston.



GALEN (A.D. 130?–?200)

After Hippocrates, Galen, the founder of experimental physiology, was the most distinguished physician of antiquity. His anatomical studies were unsurpassed for their accuracy and completeness, and his physiological findings were revolutionary.

Galen was born in Pergamum, the capital of Mysia in Asia Minor (now Bergama, Turkey). He began the study of medicine in about 146 and two years later went to Smyrna, where he attended lectures by Pelops, a celebrated physician of the time. After his studies he traveled extensively throughout the Roman Empire, finally visiting the famous medical school in Alexandria, Egypt.

In 164 he went to Rome, where he lectured and became acquainted with many high state and military officials. He returned to Pergamum, but to evade military service he settled permanently in Rome and became court physician.

Galen's achievements in anatomy and physiology were many. Since dissection of human beings had become disreputable, Galen experimented with animals, mainly dogs, goats, pigs, and monkeys. He had a great power of critical observation and wrote principally about what he could see. His descriptions of bones and muscles, such as those of the thoracic muscles and their respiratory action, were noteworthy. He also described the heart and its three layers of fibers; the lacteal vessels and the lingual and submaxillary glands; the flow of urine through the ureters to the bladder; and the motor and sensory nerves, which he had observed by sectioning the spinal cord at various levels. One of his most important contributions was the proof that arteries contain blood and not air as had been taught by the Alexandrian medical school for more than four centuries.

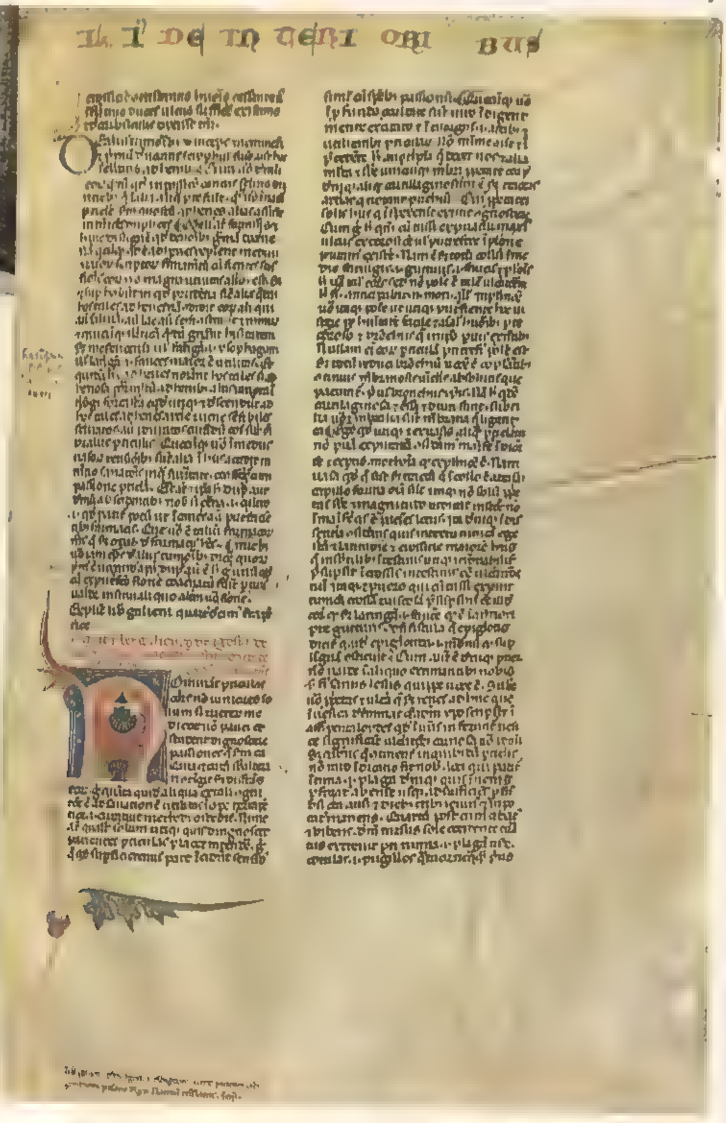
Some of his theorie[illegible] were in error, however. Among these [illegible]as his misconception of the circulati[illegible] of the blood. He believed that the se[illegible]m of the heart was full of microsco[illegible]oles through which the blood pass[illegible]m the right to the left ventricle.

Galen also had a [illegible]nterest in religion and philosoph[illegible] believed that everything in the uni[illegible] was made by a supreme being for [illegible]cific purpose. In one of his treatis[illegible] is clear that Galen believed that G[illegible]urposes could be determined by st[illegible]g His works here on Earth. Althou[illegible]len could not be considered a Christi[illegible]is monotheistic views caused his w[illegible] to be accepted by Christians of the [illegible] He was considered infallible thro[illegible]ut the Middle Ages, and it was not u[illegible] after the Renaissance that some of h[illegible]rrors and limitations came to light. [illegible]n wrote about 400 treatises in Greek, [illegible]ch he divided into groups accordin[illegible] subject—anatomy, therapy, pathol[illegible]iagnosis and prognosis, commentari[illegible] Hippocrates, philosophy, and gram[illegible]. Among his most interesting work[illegible] *Therapeutic Method*, which is a cl[illegible] text on therapy, and *Medical Art*, [illegible]mmary of the Galenic system that se[illegible]s a basic text for a thousand years. [illegible] major works of the great physicia[illegible]ude *On the Uses of the Parts of the [illegible]y of Man*, *On the Dogmas of Hippo[illegible]s and Plato*, *On Anatomical Admin[illegible]ions*, *On the Preservation of Health* [illegible] *Dieting*, *On Antidotes*, and *On the [illegible]od of Treatment*.

Many of Galen's w[illegible]gs were destroyed in the great Roman fire of 191. Of those that survived, most were lost to western Europe from the breakup of the Roman Empire until about the eleventh century, when Latin translations appeared. These were used in European medical schools until the nineteenth century.

The Greek physician Galen was a prolific writer on subjects ranging from medicine to philosophy and grammar; however, he was best known for his anatomical studies and physiological findings. Many of his writings were either destroyed in the Roman fire of 191 or lost to western Europe until the eleventh century, when Latin translations of the original Greek appeared. Some of these were used by medical schools until the nineteenth century.

Galen



GALILEO (1564–1642)

The Italian astronomer and physicist Galileo is considered the first person to establish experiment as the basis of science. His achievements in physics and astronomy were vast and of fundamental importance. He discovered the law of the pendulum, developed a theory about falling bodies, invented a hydrostatic balance, and perfected the telescope, being the first to use it to observe the skies.

He was born Galileo Galilei in Pisa, Italy, the son of a noble Florentine family

Galileo did n[illegible]nt the telescope, but he realized its [illegible]l for scientific progress and was the [illegible] use it to study the skies. The lens o[illegible]lescope that he built in 1609–1610 w[illegible]nted in an ivory frame and was powerf[illegible]h for observing the solar system. Gal[illegible] astronomical observations revealed, am[illegible]her things, that the surface of the moon is not smooth and that the Milky Way is a mass of distant stars. Because his experiments made him convinced that the Copernican theory was right, he was placed under house arrest on his estate on a hilltop near Florence, where, comforted by the affection of a few faithful friends and disciples, he spent the last few years of his life.

long impoverished. He received his early schooling at a monastery near Florence, where he studied classical languages and logic. At his father's request he entered the University of Pisa in 1581 to study medicine, a field that he soon abandoned to pursue his interest in mathematics.

It was during his first year at the university that Galileo discovered an important law, the isochronism of the pendulum. One day while in the cathedral, he noticed that the oscillations of a lamp hanging by a chain from the ceiling remained constant, though the length of the arc gradually decreased. He continued to observe the movements of the lamp, timing the oscillations with his pulse. Thus, he discovered the pendulum principle, which he later saw the possibility of also using in the regulation of clocks.

Because of a lack of funds Galileo had to leave the University of Pisa in 1585. He returned to Florence and the following year published a paper on the hydrostatic balance, which he had invented for weighing objects in water to determine their specific gravity. This made him famous throughout Italy. In 1589 his essay on the center of gravity in solids secured him an appointment to the faculty of the University of Pisa as mathematics lecturer.

While there Galileo began his thorough research into the motion of heavy bodies. At that time, only the scientific ideas ex-

pounded by Aristotle were being taught in universities; but Galileo, not fully convinced of Aristotle's contention that bodies fall with a velocity proportional to their weight, undertook a series of exciting experiments and disproved it. One of the experiments reportedly involved dropping balls from the Leaning Tower of Pisa, though this has been disputed by historians. Galileo subsequently perfected his experiments by having balls roll down planes that were inclined at different angles, thereby showing that the speed of falling bodies increases with time and that the stronger the force to which they are subjected, the greater this increase will be. In this case the force of gravity, equal for all the balls, was reduced to a greater or lesser degree by the angles of the planes. His findings convinced Galileo of the existence of a law that governs the motion of bodies subject to forces: the acceleration (change of velocity) to which a body is subjected is directly proportional to the motive force and inversely proportional to the volume of the body itself. This principle constitutes the second law of dynamics, the principle of inertia being the first one. Followers of Aristotelian teaching were greatly opposed to Galileo's new theory, holding that heavy bodies do indeed fall faster than light ones.

Meanwhile, Galileo had moved to Padua and become a professor of mathematics at the university there, a position he held for eighteen years. His lectures were popular, and soon his students began to show extreme interest in experimentation.

Toward the end of the sixteenth century, Galileo turned his attention to studies of heat and constructed a new instrument, the thermometer, which was later perfected. In 1609–1610 he learned of the invention of the telescope. Feeling that he could turn this invention to some useful purpose, he began to study lenses and built his own telescope—one powerful enough to be used for astronomical observation. As the first man to use the telescope to study the skies, Galileo made some great astronomical discoveries. He noticed that the surface of the moon is not smooth; he found the Milky Way to be a mass of distant stars; he discovered the satellites of Jupiter and named them Sidera Medicea after the Medici family; and he observed sunspots, the phases of Venus, and the unique form of Saturn.

His observations resulted in *Letters on the Sunspots* (1613), in which he maintained that the movement of spots across the face of the sun proved Copernicus correct and Ptolemy wrong. Although his experiments were convincing, he was plagued by churchmen and scientists who thought him a heretic for doubting the teachings of the ancients. He was told to give up the Copernican theory, but he gave it further support in his *Dialogue of the Two Chief World Systems* (1632), which was acclaimed throughout Europe as a masterpiece. The Holy Office, or Inquisition, however, did not share this feeling and summoned Galileo to stand trial. He was ordered to publicly renounce Copernican thought, after which he was placed under house arrest on his estate near Florence for the last eight years of his life.

Under these conditions, however, Galileo was still free to write, work, and perfect many experiments. In 1634 he completed his *Dialogue on Two New Sciences,* a summary of his early experiments in mechanics. He became blind shortly before this work was published in 1638 and died four years later.

GALOIS, ÉVARISTE (1811–1832)

In a brief lifetime of only twenty years the French mathematician Évariste Galois made outstanding contributions to higher algebra. His mathematical legacy consists chiefly of a letter he wrote to his friend Auguste Chevalier on the eve of his death in a duel. In the letter he outlined three mathematical treatises: one on elliptic integrals and two on the theory of equations.

At age twelve Évariste Galois entered the Lycée Louis-le-Grand in Paris. The discipline was so rigid that it had a negative effect, and he did not get on with his teachers.

Évariste Galois

Galois was born in Bourg-la-Reine, France, where his father was mayor. He entered the Lycée Louis-le-Grand in Paris in 1823. Although he showed great mathematical talents, he had difficulty getting along with his teachers. The mathematics textbooks did not seem adequate to him, and so he began reading primary works of masters like Joseph Louis Lagrange. At age seventeen he encountered a talented and sympathetic teacher named Louis Paul Émile Richard.

On two occasions Galois failed to pass the entrance examinations for the École Polytechnique but was accepted at the École Normale in 1830. Within a year, however, he was expelled in a political controversy. In 1831 he was arrested for making a speech that allegedly threatened the life of the king, but he was acquitted at the trial. At the age of twenty he died of wounds received in a duel with a challenger who may have been a police agent.

GALTON, SIR FRANCIS (1822–1911)

The English scientist Sir Francis Galton was the founder of eugenics, the science of selective human breeding. He advocated the application of scientific principles to bring forth positive characteristics and felt that persons with defective qualities should not be allowed to reproduce themselves. Galton began a controversy that has never been resolved, which is the question of who should set the standards of desirability and just what those standards should be. Some scientists fear that eugenics could be used for political or racist ends.

When Galton began his studies of heredity, he realized that there was a lack of relevant statistical data. He amassed data on the mental and physical traits and family relationships of about 9,000 persons. Possibly his greatest scientific achievement was the development of correlational calculus to handle this mass of data.

He studied sets of identical twins, noting that heredity could be assumed to be a constant facto[illegible] ınd that it was possible, therefore, to se[illegible]ate the effects of environment upon [illegible]ne individual. In the debate over th[illegible] relative importance of environment an[illegible] heredity, Galton stood firmly on the s[illegible] of heredity.

The geneti[illegible]iscoveries of Gregor Johann Mend[illegible] re not known to the scientific com[illegible] in Galton's time. If Galton had k[illegible] of Mendel's work, he could have pr[illegible]d much further with his own studı[illegible]

At times Ga[illegible]arried his faith in statistics to ar[illegible] extremes. He attempted, for [illegible]ole, to make a map showing the [illegible]ition of beauty in the British Isles a[illegible] mposed a table plotting the incid[illegible] of mutual bad temper in husbands a[illegible]vives.

Turning his [illegible]ntion to meteorology, Galton publis[illegible] a book in 1863 called *Meteorograph*[illegible] in which he founded the techniqu[illegible] weather mapping. He also coined th[illegible]ord *anticyclone* to describe pressu[illegible]ghs that bring good weather and [illegible] played a significant role in the est[illegible]hment of the Meteorological Office [illegible]ngland.

Galton w[illegible]orn near Sparkbrook, Birmingham[illegible]and. He was educated at Birmingh[illegible]eneral Hospital; King's College, Un[illegible]ty of London; Trinity College, Ca[illegible]ge; and St. George's Hospital, Lo[illegible] receiving his medical degree from [illegible]bridge in 1844.

With inde[illegible]nt financial means, he made a 1,7[illegible]le expedition to Africa in 1850–185[illegible] on his return he wrote two books a[illegible]t the expedition, and in 1853 the R[illegible]al Geographical Society awarded him its gold medal for his explorations.

In 1857 he settled in London to pursue his scientific studies of heredity. He was elected a fellow of the Royal Society in 1856 and was knighted in 1909. In his will he left an endowment to the University of London for a chair in eugenics.

GALVANI, LUIGI (1737–1798)

In the eighteenth century the Italian physiologist Luigi Galvani conducted experiments that revolutionized ideas about electricity. He discovered accidentally that a continuous flow of current could be induced along a conductor by bringing two dissimilar metals into contact with a moist substance. Although he did not understand the principle, his experiments stimulated further investigations into electricity; and his name is immortalized in such terms as *galvanic*, *galvanize*, and *galvanometer*.

Galvani was born at Bologna, Italy. After studying theology at the university there, he turned to medicine. In 1762 he received his degree and was appointed lecturer in anatomy. His researches on the organs of birds enhanced his reputation, and soon he was made a professor.

In the course of dissecting frogs, he noticed that when a knife touched the nerve of a dissected leg at the same time that an electric machine in the laboratory gave off a spark, the leg muscle twitched. Galvani had been using his electric machine for studying the effect of electric shock on animals. After the episode of the frog leg, however, he concentrated on that phenomenon. In time he discovered that electricity from storm clouds had the same effect as the frictional electricity from the machine.

The frog leg was a kind of electric meter: it was the first known device that showed electric current. In Galvani's time, there were instruments that indicated the presence of electricity as an electric charge, but there were none that showed electric current in motion.

Since Galvani was a practicing physician and could perform his experiments

When Luigi Galvani, in one of his experiments with electricity, touched the exposed nerve of a frog leg with a knife at the same time that an electric machine nearby was activated, the leg muscle twitched, thereby showing electric current.

only in his spare time, it wasn't until six years later that he made a second great discovery. One day in 1786 he took some frogs to the roof of the laboratory building and hung them by copper hooks onto an iron railing. It was a stormy day, and he hoped to get electricity from the clouds. While he was preparing the necessary wires, the wind blew the frogs' legs against the iron railing. Although no electricity had yet been brought down from the clouds, the legs twitched.

Galvani took the frogs—with the hooks secured through their spinal cords—back into the lab, where he put them onto an iron plate. When the legs and the copper hooks touched the plate, the legs twitched. He touched the nerve of a frog leg with a piece of copper, and the muscle with a piece of iron. The leg jumped. He tried using two pieces of copper. Nothing happened. He saw that somewhere in the circuit of nerve to muscle to iron to copper and back again there was a source of electricity. Since a motion of the nerve juices seemed to accompany the contraction, Galvani believed that the nerve was the source. He wrote the results of his experiments in the short *Commentary of the Forces of Electricity in Muscular Motion* (1791).

Controversy arose among those who favored Galvani's theory that animal tissues generate electricity; those who thought Galvani's electricity differed from other electricity; and those who sided with Alessandro Volta, Italian physicist, who believed that the electricity in Galvani's experiments originated in the metal parts of the circuit. By 1800 it was known that Volta was right.

When the Transalpine Republic was set up in 1797 after Napoleon conquered Italy, Galvani refused to take a loyalty oath and consequently lost his position at the university. He died the following year, aggrieved by the death of his wife and by criticism of his scientific beliefs.

GASSER, HERBERT SPENCER
(1888–1963)

The 1944 Nobel Prize in physiology or medicine was conferred upon Herbert Spencer Gasser, U.S. physiologist, for advancing the understanding of pain and reflex action through his research on nerve fibers. The co-winner was Joseph Erlanger, Gasser's collaborator and former teacher. (*See* Joseph Erlanger.)

With the aid of a cathode-ray oscilloscope, they showed that groups of nerve fibers conduct electric impulses at rates directly proportional to the thickness of the fiber—thicker fibers convey impulses faster—and that nerve trunks contain fibers of various sizes and functions.

Gasser was born in Platteville, Wisconsin. He graduated from the University of Wisconsin, Madison, where he was one of Erlanger's physiology students. In 1915 Gasser received his medical degree from Johns Hopkins University Medical School, Baltimore, Maryland. After serving in the chemical warfare service during World War I, he joined the faculty of Washington University, St. Louis, Missouri, where Erlanger was then a professor. Gasser was appointed professor in 1921. In the early 1920s Gasser and Erlanger began their studies of nerve potentials, leading to their joint award.

In 1931 Gasser was appointed head of the physiology department at Cornell University Medical College, New York City. He became director of the Rockefeller Institute for Medical Research in 1935 and held that position until his retirement in 1953.

One of Gasser's outstanding contributions was his study of the finest of all nerve fibers—the unmyelinated fibers (having no fatty sheath), which consist of a cylinder of protoplasm covered with a membrane about one-millionth of a centimeter in thickness. He explained their functional properties and anatomical structure.

GAUSS, JOHANN KARL FRIEDERICH
(1775–1855)

Among such mathematicial geniuses as Archimedes and Sir Isaac Newton can be found Johann Karl Friederich Gauss. He was not only a superb mathematician but also a first-rate astronomer, and he had a working knowledge of classical and modern European literature as well. He never stopped learning: in his sixties he decided to teach himself the Russian language.

Gauss was born in Brunswick, Germany. He was extremely precocious: by the age of three he had taught himself to read and was correcting his father's computations; at the age of eleven he went to secondary school and distinguished himself in mathematics and languages; and at the age of fourteen he was presented to the Duke of Brunswick, who decided to subsidize his further studies.

Most of his fundamental mathematical discoveries were made between the ages of fourteen and seventeen. The arithmetico-geometric mean in particular occupied his attention.

In 1792 he entered the three-year Collegium Carolinum in Brunswick, where he did extensive research in number theory, concentrating on the frequency of primes. While in Brunswick he discovered the method of least squares in 1794 and the law of quadratic reciprocity, as well as Newton's *Principia*. He was deeply inspired by the *Principia* and all his life retained an admiration for Newton.

Johann Gauss

Johann Gauss spent much of his life in Göttingen, Germany, first as a student at the university and later as professor of mathematics and director of the observatory.

Moving on to the University of Göttingen, Gauss read extensively in the works of the great masters and began to realize more fully his own potential as a master. He studied there from 1795 to 1798. During this period he demonstrated a method for constructing an equilateral polygon of seventeen sides, using only a compass and a straightedge. Furthermore, he proved the impossibility of constructing a seven-sided figure in this manner. From this time the proof of the impossible gained steadily in importance in mathematics.

The fundamental theorem of algebra was proved by Gauss in 1799. Two years later he took on the fundamental theorem of arithmetic and proved that, also.

One of Gauss's greatest achievements was the writing of *Disquisitiones arithmeticae*, which was published in 1801. In this book he established his theory of arithmetical forms.

When Ceres, the first planetoid, was discovered in 1801, Gauss turned his attention to astronomy and calculated the orbit of Ceres. Others had tried and failed, but the twenty-six-year-old Gauss was triumphant. Later, in 1809, he published another major work, this one telling how to determine a planet's orbit. The 1,001st planetoid was named Gaussia in his honor.

In 1807 Gauss was appointed professor of mathematics and director of the observatory at Göttingen. Although he received many other offers of positions, he remained firmly settled at Göttingen.

For years much of his time was spent in making a geodetic survey of the kingdom of Hanover, which he had been commissioned to do in 1818. In the course of the survey he invented the heliotrope, an instrument that uses reflected sunlight to project lines of measurement on the Earth's curved surface.

In the 1830s he turned to research on electricity and magnetism. Much of this work was done in collaboration with Wilhelm Weber. By 1833 Gauss had devised an electric telegraph, and in 1836 he and Weber founded the Magnetic Union.

His collected works were published from 1863 to 1933. He taught and inspired many fine mathematicians. Today his work remains a testament to his life.

Joseph Gay-Lussac

His birthplace at Saint-Léonard, west central France, was the scene of Joseph Gay-Lussac's early schooling. It was there that he first studied under the guidance of a priest.

GAY-LUSSAC, JOSEPH LOUIS (1778–1850)

The French chemist and physicist Joseph Louis Gay-Lussac was a pioneer in the study of gases. In 1802 he published a paper showing that all gases expand by equal amounts as the temperature rises, and in 1804 he participated in two balloon flights sponsored by the French Academy. On the flights, he made observations on magnetism and collected samples of air at different heights. Some of his studies showed that the composition of air is constant at various heights, and this fact was one of the bases of the modern science of meteorology.

In 1809 he published a paper on the combination of gases, containing what is still known as Gay-Lussac's law: gases combine by volume in simple proportions, and the resultant gas has a volume that is a simple ratio of the original gases. This law quickly became important in determining atomic weights.

By fusing iron and potash, Gay-Lussac was able to make potassium in 1808. He then used potassium to isolate boron from boric acid. Two papers on fermentation were published by him in 1810 and 1815, respectively. While he was studying fermentation, he also worked with Louis J. Thénard on making improvements in the methods of organic analysis. In 1813 and 1814 he investigated the chemistry of iodine.

His last major piece of pure research dealt with prussic, or hydrocyanic, acid. In 1815 he described its composition and showed that the acid contains hydrogen but no oxygen. This discovery disproved the theory of the famed Antoine Laurent Lavoisier that all acids must contain oxygen. Gay-Lussac proposed that the names of acids that do not contain oxygen should carry the prefix *hydro-*.

Gay-Lussac was born in Saint-Léonard, France, the son of a judge and the grandson of a physician. He entered the École Polytechnique in 1797 but changed to the École des Ponts et Chaussées two years later. In 1802 he was appointed an assistant to Antoine F. Fourcroy at the École Polytechnique, succeeding him as professor of chemistry in 1810. Meanwhile, in 1806, he had been elected to the Institut de France. From 1808 to 1832 he was professor of physics at the Sorbonne, a post that he resigned to become a chemistry professor at the Jardin des Plantes.

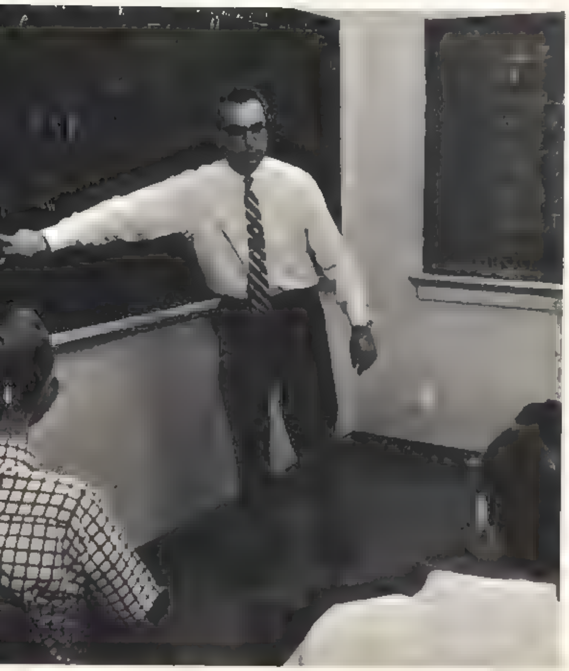
When Gay-Lussac became famous, his services as a technical adviser were greatly in demand by government and industry. In 1829 he was appointed assayer to the mint. Among his services to industry was the invention of a tower (which bears his name) for recovering oxides of nitrogen during the manufacture of sulfuric acid.

Late in life he turned to public service. He was elected to the Chamber of Deputies in 1831 and the Chamber of Peers in 1839.

GELL-MANN, MURRAY (1929–)

The U.S. physicist Murray Gell-Mann won the 1969 Nobel Prize in physics for "contributions and discoveries concerning the classification of elementary particles and their interactions." He is credited with making understandable order of the seeming chaos of subatomic physics. Before he developed the strangeness theory, which explained the energy states of particles by describing how they moved, scientists had been baffled by the behavior and relationships of the many known particles and antiparticles that make up the nucleus of an atom. By grouping the particles according to categories having common characteristics, Gell-Mann developed his eightfold way of approximate symmetry. Like the periodic table of the elements, Gell-Mann's groupings had gaps that enabled him to predict the existence of unknown particles. Later he predicted that even smaller particles—which he called quarks—exist and make up the particles of the atom's nucleus.

Gell-Mann was born in New York City, the youngest son of Austrian immigrants. His father—a mathematician, astronomer,



Murray Gell-Mann

and archaeologist—recognized that the boy was a prodigy and sent him to a private school. He took his bachelor's degree at Yale University in 1948 and his doctorate at the Massachusetts Institute of Technology, Cambridge, in 1951. After teaching at the University of Chicago (1952–1954), he taught at the California Institute of Technology, Pasadena, becoming R. A. Millikan Professor of Theoretical Physics in 1967. In addition, he worked at the Institute for Advanced Study at Princeton, held several visiting professorships, and was a consultant to the Institute for Defense Analyses, Rand Corporation, National Aeronautics and Space Administration, and Los Alamos Scientific Laboratory in New Mexico.

In 1959 Gell-Mann received the Dannie Heineman Prize from the American Institute of Physics and in 1960 was elected to the National Academy of Sciences. He was regarded by some colleagues as the scientific successor to Albert Einstein.

GESNER, KONRAD VON (1516–1565)

The Swiss naturalist and physician Konrad von Gesner provided the starting point for modern zoology in his monumental work *Historia animalium*. The first four volumes—dealing with birds, fishes, and quadrupeds—were published from 1551 to 1558. A fifth volume, dealing with snakes, was published posthumously in 1587.

In his own time Gesner was known primarily as a botanist. The late Middle Ages saw a rebirth of natural science, which had been dormant since ancient times. Gesner described approximately 500 plants unknown to such ancient masters as Aristotle.

Although his fame rests mainly on his scientific work, Gesner was a scholar with broad interests spanning many fields of endeavor. In 1545 he published *Bibliotheca universalis*, a catalog of all known works in Latin, Greek, and Hebrew, complete with summaries of each book. He also published a vast twenty-volume encyclopedia of general knowledge in 1548 and 1549 and planned another volume on theology but never completed it. His *Mithridates de differentiis linguis*, published in 1555, is an account of 130 languages.

Endowed with artistic talents, Gesner made drawings of many animals to illustrate his works. His illustrations were notable for their realism in an age when artists tended to make fanciful portrayals of nature. He was the first to present drawings of fossils but did not know that they represented ancient life.

Mountain climbing interested Gesner, both as a sport and as a means of making nature studies. After climbing a 6,299-foot mountain, the Gnepfstein, he wrote an account of his findings, *Descriptio Montis Fracti sive Montis Pilati*.

Gesner was born in Zürich, Switzerland. He studied in Strasbourg, Bourges, Montpellier, and Basel, where he received a medical degree in 1541. At first he practiced medicine in Zürich and then became a lecturer in physics at the Carolinum there. He had resumed the practice of medicine, however, when there was an outbreak of the plague. Refusing to abandon his patients during the epidemic, he fell victim to it himself.

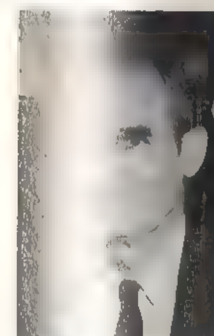
GIAUQUE, WILLIAM FRANCIS (1895–)

The U.S. chemist William Francis Giauque won the 1949 Nobel Prize in chemistry for his studies of very low temperatures. In 1926 he first proposed his magnetic cooling method for reaching temperatures approaching absolute zero. He began by placing magnetic salt under the influence of a magnetic field; the next step was to place the salt in a container surrounded by liquid helium and to drop the temperature of the salt. When the magnetic field was removed, the molecules of the salt absorbed heat from the helium, lowering temperatures once again.

The first successful experiment using this method was performed by Giauque and D. P. MacDougall in 1933. The method has become basic to low-temperature research and has made it possible to reach temperatures as low as a small fraction of a degree above absolute zero.

In 1929 Giauque and H. L. Johnston discovered oxygen's isotopes of atomic weights 17 and 18. The discovery revealed a difference between chemical and physical atomic weights and provided a way to compute that difference. (In 1961 the carbon-12 system was adopted for both.) They also found that oxygen-18 could be used as a tracer in studying reactions of the oxygen atom.

Another of Giauque's accomplishments was establishing the third law of thermodynamics as a fundamental law of science. Further, he formulated ways of understanding exceptions to the law. Moving on to quantum statistics, he provided an experimental base for additional work in this field.



William Giauque

Giauque was born in Niagara Falls, Ontario, Canada, of U.S. parentage. He attended Niagara Falls Collegiate Institute and then the University of California at Berkeley, where, as an undergraduate, he did research on the measurement of entropy at low temperatures. He received his bachelor's degree in 1920. His doctoral thesis in 1922 dealt with entropy in glycerine glass. He then joined the Berkeley faculty as an instructor, being promoted to professor in 1934. During World War II he worked for the U.S. government with a group of scientists producing mobile units of liquid oxygen.

In addition to the Nobel Prize, he received many honors, including the Chandler, Gibbs, and Lewis awards. He was elected to the National Academy of Sciences in 1936.

GIBBS, JOSIAH WILLARD (1839–1903)

The U.S. physicist Josiah Willard Gibbs was one of the founders of chemical thermodynamics. He is also remembered for his work on statistical mechanics. Primarily a theorist, he performed few experiments. The comprehensive applica-

tion of mathematics to chemistry was one of Gibbs's main accomplishments; but since chemists of his time knew little mathematics, g[illegible] communications problems arose. It took some years before his fame spread to Europe; one of his earliest supporters there was the Scottish scientist James Clerk Maxwell.

The most famous of Gibbs's papers was "On the Equilibrium of Heterogeneous Substances," published between 1876 and 1878 in *Transactions of the Connecticut Academy of Sciences*. This paper led to the development of the phase rule, which solidly established his reputation as a scientist. The phase rule involves a simple equation ($P + F = C + 2$) invaluable in handling the equilibrium between different phases—gas, liquid, or solid.

Other papers published in the *Transactions* included "Graphical Methods in the Thermodynamics of Fluids" and "A Method of Geometrical Representation of the Thermodynamic Properties of Substances by Means of Surfaces," both of which appeared in 1873. His teaching notes were gathered into a textbook called *Vector Analysis*, which was published in 1901. His last work, *Elementary Principles in Statistical Mechanics*, was issued in 1902.

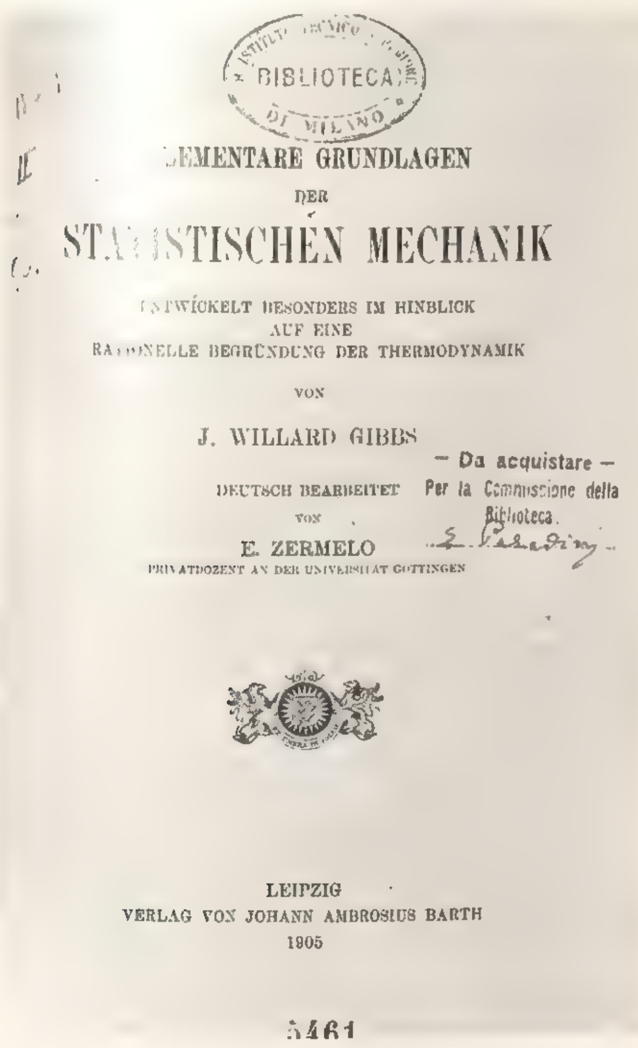
Gibbs's complete papers were assembled and published by Yale University Press under the title *The Collected Works of J. Willard Gibbs*. One of his students, L. P. Wheeler, wrote a comprehensive biography with extensive source material, entitled *Josiah Willard Gibbs, the History of a Great Mind.*

Gibbs was born in New Haven, Connecticut. He received his undergraduate degree from Yale University in 1858. The first Yale doctorate for an engineering thesis was awarded to him in 1863. After tutoring at Yale, he studied further in Europe: at Paris (1866–1867), Berlin (1867–1868), and Heidelberg (1868–1869).

In 1871 he was appointed professor of mathematical physics at Yale, a post he held until his death in spite of many offers to teach elsewhere. The position was an honorary one, and he lived on independent means.

The Royal Society awarded Gibbs its Copley Medal in 1901 for his work on the second law of thermodynamics. He also received the society's Rumford Medal. In 1950 he was elected to the Hall of Fame for Great Americans.

In 1902, after [illegible] months of preparation, Josiah Gibbs published his last work, *Elementary Principles in Statistical Mechanics;* the second edition appeared in 1905.



BIBLIOTECA DI MILANO

ELEMENTARE GRUNDLAGEN

DER

STATISTISCHEN MECHANIK

ENTWICKELT BESONDERS IM HINBLICK AUF EINE RATIONELLE BEGRÜNDUNG DER THERMODYNAMIK

VON

J. WILLARD GIBBS

DEUTSCH BEARBEITET VON

E. ZERMELO

PRIVATDOZENT AN DER UNIVERSITÄT GÖTTINGEN

— Da acquistare — Per la Commissione della Biblioteca.

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Josiah Gibbs

GILBERT, GROVE KARL (1843–1918)

Among the first men to survey the geology of the western United States was the eminent U.S. geologist Grove Karl Gilbert. Some of the observations and conclusions resulting from his fieldwork, such as his statement of the law of unequal slopes, gave new geological insight. He also estimated geological time by relating the precession of the equinoxes to the rate of sedimentary deposit in the Colorado River.

Gilbert was born at Rochester, New York, and educated at the University of Rochester. In 1862 he received his bachelor's degree and in 1872 his master's. From 1863 to 1868 he worked as an assistant at the Ward Museum in Rochester.

In 1868 Gilbert began the first of a long series of geological trips when he set out with the second Ohio State Survey. He was with the Ohio survey until 1870, and in the following year he was assigned to the Walker Survey of the western United States. On this survey Gilbert traveled up the lower Colorado River canyons, overland through central Arizona, and down the Colorado River to the Gulf of California.

He joined the John Wesley Powell Survey in 1875, which took him to Utah. Some of Gilbert's most important work, including his study of the Henry Mountains, resulted from that expedition. In 1879 he was appointed to the U.S. Geological Survey as a senior geologist, and from 1889 to 1892 he was its chief geologist.

Gilbert published papers on the basin, range, and plateau regions of the United States. He also described and named ancient Lake Bonneville in Utah. In his *Geology of the Henry Mountains* he gave the first description of a laccolith. His other published works include *Bonneville Monograph* (1890) and *History of the Niagara River* (1890). In 1908 he won the Walker Grand Prize of the Boston Society of Natural History.

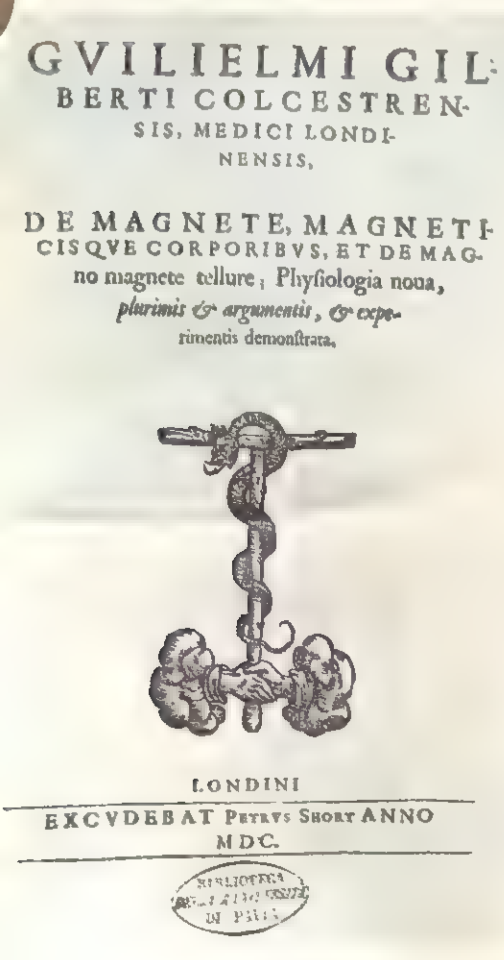
GILBERT, WILLIAM (1544–1603)

One of the earliest scientific investigators of magnetism was the English physician and physicist William Gilbert. For making the first scientific studies of electric attractions between certain objects,

he was known as the Father of Electricity.

Gilbert presented his findings on magnetism in his treatise *De magnete, magneticisque corporibus, et de magno magnete tellure* (1600), regarded as the first major scientific work published in England. At the time he began his research, lodestones were the most powerful magnets known. By using the scientific method of experiment and direct testing, Gilbert disproved many misconceptions concerning magnetism. He also found that the magnetic strength of lodestone could be increased with iron-pole pieces, that metal rods became magnetized when stroked with lodestone, and that iron bars became magnetized when left lying for some time in the direction of the Earth's magnetic field.

William Gilbert



GVILIELMI GILBERTI COLCESTRENSIS, MEDICI LONDINENSIS,

DE MAGNETE, MAGNETICISQVE CORPORIBVS, ET DE MAGno magnete tellure; Physiologia noua, *plurimis & argumentis, & experimentis demonstrata.*

LONDINI

EXCVDEBAT PETRVS SHORT ANNO MDC.

William Gilbert's principal treatise, *De magnete, magneticisque corporibus, et de magno magnete tellure* (1600), which presented his findings on magnetism, was distinguished by its adherence to the scientific method of investigation by experiment.

By studying the behavior of magnetic compasses and the phenomena of magnetic dip, Gilbert concluded that the Earth is a giant magnet. He suggested that compass needles point toward the Earth's magnetic poles rather than toward the heavens, as had been previously supposed. The unit of magnetomotive force, the gilbert, was named in his honor.

Gilbert also studied static electricity that is apparent in amber, which will attract any lightweight object. He discovered that when rubbed, a number of other substances acquire the same electrostatic attractive powers as amber. This attraction differs from magnetism, which is present in only certain matter, and so Gilbert called these other substances with attractive powers *electrics.* He was the first person to use the words *electricity, electric attraction, electric force,* and *magnetic pole.*

Gilbert also theorized on the structure of the universe. He accepted Copernicus' ideas and was the first to propose an alternative to Pythagoras' notion that the planets are kept on their courses by the celestial spheres. Gilbert came to the conclusion that the planets are governed by some type of magnetic attraction.

Gilbert was born at Colchester, Essex, England. He studied medicine at St. John's College, Cambridge, graduating in 1569. After traveling about Europe he established a private medical practice in London in 1573. He had great success as a physician and in 1599 was elected president of the College of Physicians. In 1601 he was appointed physician to Queen Elizabeth I. After her death he served as physician to James I.

GLASER, DONALD ARTHUR
(1926–)

For inventing an instrument that detects the paths of high-energy atomic particles, U.S. nuclear physicist Donald Arthur Glaser won the 1960 Nobel Prize in physics, thus becoming, at the age of thirty-four, one of the youngest Nobel laureates. His device, known as a bubble chamber, makes possible the observation and recording of rare nuclear phenomena.

Glaser, a native of Cleveland, Ohio, graduated in 1946 from the Case Institute of Technology (now Case Western Reserve University) in that city. In 1950 he earned his doctorate at the California Institute of Technology, Pasadena, and joined the faculty of the University of Michigan, Ann Arbor, where he became professor of physics in 1957. He held the same position at the University of California at Berkeley from 1959 to 1964, when he was made pr[illegible]sor of physics and molecular biology.

In the early 1950s [illegible]aser was engaged in research on [illegible] particles produced in high-energy [illegible]mic-ray collisions. The cloud cham[illegible]en in use for investigating the inte[illegible]n of atomic particles had been inv[illegible] by C. T. R. Wilson early in the [illegible]tieth century and, using gas as its m[illegible]a, was inadequate for studying the [illegible]-energy particles produced by gian[illegible]rticle accelerators. Seeking a high[illegible]sity medium, Glaser turned to super[illegible]ed liquids. In 1952 he developed the [illegible] bubble chamber—a small glass bo[illegible] containing a few cubic centimeters [illegible]diethyl ether. Bubble chambers form [illegible]calized tracks of high-speed particle[illegible]eracting in a large volume of high-[illegible]ty liquid; the choice of liquid depend[illegible]on the target material, the particle [illegible], and practical convenience. From [illegible]h-speed photographs of the bub[illegible] tracks taken through the strong gla[illegible]ndows of the chamber, precise mea[illegible]ents can be made of the details of [illegible]ar processes. New events can be re[illegible]d every few seconds when the cham[illegible]s exposed to bursts of cosmic ray p[illegible]les or high-speed particles from a[illegible]rators.

Glaser was elected [illegible] the National Academy of Sciences [illegible]62. By then bubble chambers six fe[illegible]liameter and holding 150 gallons of [illegible]quid were in operation. He was also honored with many professional awards, including a prize from the Physical Society of London in 1958, the American Physics Society Prize in 1959, the Gold Medal from Case in 1967, and the Alumni Distinguished Service Award of the California Institute of Technology in 1967.

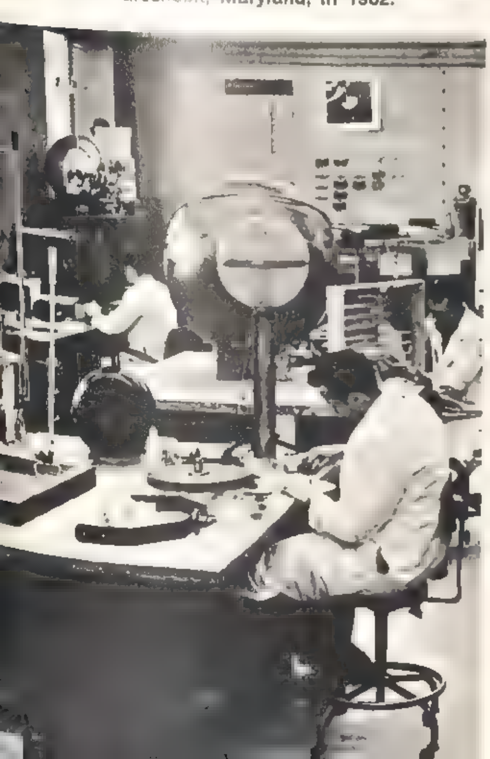
GODDARD, ROBERT HUTCHINGS
(1882–1945)

The man largely responsible for initiating the space age was Robert Hutchings Goddard, known as the Father of Rocketry. Some called him "moon mad" when he launched his early rockets; but when U.S. officials questioned German scientists about the V-2 rockets after World War II, the German experts asked in wonderment why the U.S. government had not questioned Goddard, whose technical accomplishments Germany had borrowed so freely.

While a student at Worcester Poly-

technic Institute in Massachusetts, Boston-born Goddard began to speculate about ways of using rockets to reach outer space. He earned his doctorate at Clark University, Worcester, in 1911 and was a member of its faculty for almost thirty years after teaching for a time at Worcester Polytechnic and Princeton University.

Although Robert Goddard's first rocket, launched in 1926, was only about four feet high and six inches around, it was the forerunner of the [illegible] lunar rockets. In appreciation of his pioneering efforts in this field, the National Aeronautics and Space Administration dedicated the Goddard Space Flight Center at Greenbelt, Maryland, in 1962.



The Smithsonian Institution published Goddard's report "A Method of Reaching Extreme Altitudes" in 1919 and furnished funds for his rocket research. His first great advance beyond earlier solid-fuel rockets came in 1923 when he tested the first of a new type of rocket engine using liquid fuels. In 1926 he launched his first rocket. It was only about four feet high and six inches around, but it was the ancestor of the behemoths that later sent men to the moon. Goddard sent up a larger rocket in 1929 near Worcester. It was the first to carry instruments—camera, thermometer, and barometer. Complaints about the noise, however, persuaded officials to put a stop to the rocket experiments in Massachusetts.

Supported by Clark University and the Guggenheim Foundation, he continued his work with liquid-fuel rockets and gyroscopic controls at a desert site near Roswell, New Mexico. Between 1930 and 1935 Goddard launched rockets to a height of 1½ miles and at speeds up to 550 miles per hour. He developed the theory of step rockets, consisting of several stages, as a means of reaching the moon. One of his more than 200 patents was a device for a multistage rocket. The potential of his work, however, went largely unrecognized.

Goddard was employed by the U.S. Navy in World War II to develop rocket motors and jet-assisted takeoff devices for aircraft. He was engaged in this work at Annapolis, Maryland, at the time of his death.

Germany made unauthorized use of his patents in its development of the V-2 rockets, which besieged London, England, and other Allied targets during World War II. The U.S. government, too, did the same thing in its space-probe efforts, but in 1960 it paid the Guggenheim Foundation $1 million for infringement of Goddard's patents.

Experience in handling and launching large rockets was gained between 1946 and 1951 when about seventy V-2 missiles, brought in component parts from Germany, were fired from the White Sands (New Mexico) Proving Ground—not far from Goddard's old test site. In 1962 the National Aeronautics and Space Administration dedicated the Goddard Space Flight Center at Greenbelt, Maryland. Although he did not live to see his country enter the space age, Goddard was largely responsible for its ability to do so.

GOEPPERT. See Mayer, Maria Goeppert.

GOLDSCHMIDT, VICTOR MORITZ (1888–1947)

The man credited with being the founder of crystal chemistry and modern geochemistry was Victor Moritz Goldschmidt, a Swiss-Norwegian geochemist, mineralogist, and petrologist. By studying the occurrence of elements in rock and mineral substances, Goldschmidt worked out a method for predicting the elements that should appear in different types of minerals. In this work he made use of the new discoveries regarding atomic and ionic sizes. Another notable achievement was his contribution of a new basis for the theory of the transformation of minerals by changes in pressure and temperature.

Goldschmidt was born at Zürich, Switzerland, but in the early 1900s his family moved to Norway, where his father had accepted a professorship in chemistry at the University of Oslo. Eventually, all the members of the family became Norwegian citizens. Goldschmidt studied chemistry, geology, and mineralogy at the University of Oslo and received his doctorate in 1911.

The following year he joined the faculty. In 1914 he became director of the Mineralogical Institute, which he left in 1929 for a professorship at the University of Göttingen in Germany.

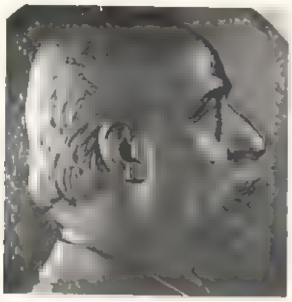
Because of the Nazi regime Goldschmidt was forced to leave Germany in 1935 and return to Norway. He then became director of the Geological Museum at Oslo. In 1940, however, the Germans occupied Norway, and Goldschmidt, a Jew, was imprisoned in concentration camps. He fled to England two years later and for a while worked at the Macaulay Institute in Aberdeen, Scotland. After the war he returned to Oslo, but less than a year later he died of cancer.

GOLGI, CAMILLO (1843–1926)

The key to knowledge of the finer structure of the nervous system dates from the research of Camillo Golgi, Italian histologist, who shared the 1906 Nobel Prize in physiology or medicine with Santiago Ramón y Cajal, a Spanish histologist. In 1873 Golgi devised a method for staining nervous tissue with silver salts, which revealed cellular components not visible when organic dyes were used. He published the results the following year. (*See* Santiago Ramón y Cajal.)

Golgi, the son of a physician, was born in Cortone, Italy. He entered the field of

medicine and received his degree in 1865 from the University of Pavia. After serving as a physician in a Pavia hospital for seven years, he became chief physician at the home for incurables in the village of Abbiategrasso. While there he worked out the method of silver nitrate staining.



Camillo Golgi

Slides prepared by Camillo Golgi, famous for his silver nitrate method of staining nerve cells and fibers, are still preserved at the University of Pavia.

In 1875 he was appointed professor of histology—the microscopic study of tissues—at Pavia. Later he went to Siena as professor of anatomy, but he returned to Pavia as professor of histology in 1880 and soon transferred to the chair of general pathology.

In 1883 Golgi classified multipolar nerve cells with many branching processes, known as Golgi cells, that establish connections with other nerve cells. The discovery of these cells in which the main process (axon) does not become a nerve fiber led to the conception of the neuron as the unit of the nervous system. A formation in the cytoplasm of cells, which Golgi described in 1898, is still known as the Golgi apparatus.

Aside from histological research, Golgi was known for important observations on malaria. He distinguished between different varieties of the disease and showed that the severity of a malarial attack depends upon the number of parasites in the blood.

GORGAS, WILLIAM CRAWFORD (1854–1920)

The mosquito-control program introduced in Panama by U.S. army surgeon William Crawford Gorgas was a major factor in the completion of the Panama Canal. Two of the main obstacles to the engineering feat were yellow fever and malaria. In two years Gorgas eliminated yellow fever from the canal region and brought malaria under control.

Gorgas was born near Mobile, Alabama. He was educated at the University of the South, Sewanee, Tennessee, and at Bellevue Hospital Medical College, New York City. After receiving his medical degree in 1879, Gorgas entered the U.S. Army Medical Corps and later served as a major in the Spanish-American War. Following the Santiago expedition, he was sent to Havana, Cuba, to oversee yellow-fever patients.

From 1898 to 1902 he was in charge of sanitation measures in Havana, where he conducted experiments on the transmission of yellow fever by the mosquito. His success in ridding Havana of yellow fever led to his appointment in 1903 as assistant surgeon general, with the rank of colonel.

The apogee of his professional life came in 1904 when he was sent to Panama. Systematically, he got rid of the mosquito's watery breeding grounds by either emptying them or covering them with kerosene. His brilliant administration made possible the successful conclusion of the Panama Canal project.

In 1907 Gorgas was appointed to the Isthmian Canal Commission by U.S. President Theodore Roosevelt, and in 1908 he was U.S. delegate to the first Pan-American medical congress. He served as president of the American Medical Association in 1908–1909.

Gorgas became surgeon general of the U.S. Army in 1914, with the rank of brigadier general. He was elevated to the rank of major general in the following year.

After his retirement in 1918 Gorgas became permanent director of the yellow-fever work done by the International Health Board of the Rockefeller Foundation. He directed investigations of yellow fever in both Ecuador and Guatemala, and in 1919 he accepted a contract with Peru to direct a sanitary program there.

In 1950 Gorgas was elected to the Hall of Fame for Great Americans. Established in his honor were the Gorgas Memorial Institute of Tropical and Preventive Medicine, Inc., Washington, D.C., and the Gorgas Memorial Laboratory of Tropical Research, Panama.

GRAHAM, THOMAS (1805–1869)

One of the founders of physical chemistry and the Father of Colloid Chemistry was the Scottish chemist Thomas Graham. He measured the diffusion rate of gases and formulated Graham's law. Later he studied the diffusion of one liquid into another and made the first investigations in colloid chemistry. Many of the terms used in colloid chemistry were invented by him.

Graham, the son of a wealthy businessman, was born at Glasgow, Scotland. Contrary to his father's insistence that he study for the ministry, Graham pursued a career in science; and his father, therefore, refused to pay for his education. By teaching and lecturing Graham supported himself; and in 1826 he obtained a degree from the University of Glasgow. For a while he taught chemistry at Glasgow, and in 1830 he became professor of chemistry at the Andersonian Institution in Edinburgh. From 1837 to 1855 he held a professorship at University College in London. He became master of the mint in 1855, remaining in that post until his death.

In the 1820s Graham began to study the diffusion of one gas into another. He slowed down the rate of diffusion first by separating the gases with a plaster of Paris plug and later by using fine tubes or a platinum plate with a tiny hole in it. In this way he was able to measure the rate of diffusion. From these studies he formulated Graham's law: the rate of diffusion of a gas is inversely proportional to the square root of its density.

In 1833 Graham studied the three forms of phosphoric acid—metaphosphoric, pyrophosphoric, and orthophosphoric. From this investigation he formulated the concept of polybasic acids. He also did research on the water of crystallization, on alcoholates, and on palladium hydride.

Graham's other major work was his study of the diffusion of one liquid into another. He noted that, as with gases, some types of liquids diffuse more slowly than others. Experimenting in 1861, he slowed the diffusion rate of liquids by separating them with a sheet of parchment. Materials that diffuse rapidly, such as sodium chloride and copper sulfate, passed through the parchment; materials that diffuse slowly, such as gum arabic and gelatin, would not pass through the parchment.

At the time Graham was conducting

Thomas Graham

his experimen types of substances that passed t the parchment were known to ex crystals; the crystal forms of the materials were not known. Gra therefore, separated these substan to two classes, crystalloids and co —colloids being substances that v not pass through the parchment.

In 1836 G n became a fellow of the Royal S . He was one of the founders of London Chemical Society and of t avendish Society, serving as presi of the former in 1841 and of the l n 1846.

GRANIT, RA R ARTHUR (1900–)

The Swe hysiologist Ragnar A. Granit shar 1967 Nobel Prize in physiology o licine with two U.S. scientists—Hal K. Hartline and George Wald. Gra nducted research into the physiol f vision, playing a major role in loping a sophisticated understand f how visual perception works, and motor control by muscular afferents. The Nobel Prize citation singled out G nit's early color-reception research, noting that he was the first scientist to demonstrate how different retinal nerves react to different wavelengths of light. (*See* Haldan Keffer Hartline; George Wald.)

Ragnar Granit

Granit was born in Finland but became a naturalized Swede. He graduated from the Swedish Normal Lyceum in Helsinki in 1919, earned his medical degree at the University of Helsinki in 1927, and taught there until 1940. Two years were spent as a fellow in medical physics at the University of Pennsylvania's Eldridge Reeves Johnson Research Foundation, where Hartline also worked. Granit also studied neurophysiology at Oxford University and lectured at Yale University and before the Physical Society in London.

He was given a personal research chair at the Royal Caroline Institute in Stockholm, Sweden, in 1940, and five years later a special chair of neurophysiology. That same year, 1945, he delivered the Thomas Young Oration of the Physical Society in London. In 1954 he gave the Silliman Lecture at Yale, in 1960 he was elected to the Royal Society of London, and in 1967 he was a visiting professor at St. Catherine's College, Oxford, and delivered the Sherrington Lecture of the Royal Society of Medicine in London. One of his best-known books is *Sensory Mechanisms of the Retina.*

GRAY, ASA (1810–1888)

The U.S. plant taxonomist Asa Gray was one of the most distinguished botanists of his time. He concentrated on the systematization of North American flora, and his published works on the subject are respected for their scientific value even up to the present day.

Gray was born at Sauquoit, New York, and studied medicine at Fairfield Academy. Although he received his medical degree in 1831, he never practiced; instead, he took a job teaching science at a high school in Utica, New York.

In the mid-1830s he assisted John Torrey and collaborated with him on *Flora of North America* (two volumes, 1838–1843). In 1835 Gray was appointed curator and librarian of the New York Lyceum of Natural History. He became professor of natural history at Harvard University in 1842, and through his efforts the university became the leading center of botanical study in the United States. He developed a herbarium and library there, which were later named after him.

Gray was one of the earliest plant geographers. He made trips to Europe to study European specimens similar to those found in North America. In 1859 he published a highly original paper stating the relationship of the botany of Japan to that of North America. His numerous published works include *Elements of Botany* (1836), *Botanical Textbook* (1842; renamed *Structural Botany,* 1879), *Manual of the Botany of the Northern United States* (1848), *First Lessons in Botany and Vegetable Physiology* (1857), *How Plants Grow* (1858), *How Plants Behave* (1872), *Darwiniana* (1876), and *Syntopical Flora* (1878).

For many years Gray corresponded with the English naturalist Charles Darwin. In 1857 Darwin wrote Gray a letter describing the theory of evolution. Although Gray was a devout Protestant, he accepted Darwin's views and became an outspoken supporter of Darwinism, reconciling his religious beliefs with the theory of evolution by maintaining that natural selection is a God-directed force rather than a random process. (*See* Charles Robert Darwin.)

Gray was one of the original members of the National Academy of Sciences, and in 1872 he was elected president of the American Association for the Advancement of Science. In 1900 he was chosen as one of those to be honored in the Hall of Fame for Great Americans.

GRAY, ELISHA (1835–1901)

By just a few hours the U.S. electrician and inventor Elisha Gray missed all of the fame and fortune accorded to the inventor of the telephone. He and Alexander Graham Bell engaged in a long and bitter legal battle over claims to its invention. Finally, the U.S. Supreme Court decided in favor of Bell. Gray, however, patented several other important inventions in the field of telecommunications and was one of the founders of the business enterprise that became the Western Electric Company.

Gray was born near Barnesville, Ohio. Before he had completed his education in the public schools, his father died; and he was forced to leave school and find work. At first he took up blacksmithing; but finding that he was not strong enough for that trade, he turned to carpentry and boatbuilding.

Encouraged by a friend to seek a college education, Gray returned to school when he was twenty-two years old. He attended preparatory school for three years and Oberlin College for two years. While trying to get an education he supported himself by carpentry. The strain of overwork during those years had an adverse effect on his health, and for five years afterward he was severely limited in his activities.

At Oberlin, Gray had become interested in the physical sciences, particularly in electrical apparatus. Beginning in 1867 he turned out a number of electrical inventions, including a self-adjusting telegraph relay, a telegraph switch and annunciator, a telegraphic repeater, and a perfected typewriting telegraph.

In 1872 he moved to Chicago, Illinois, and in partnership with E. M. Barton established the firm of Gray and Barton, which later became the Western Electric Company. Gray stayed with the firm for about two years and then left to devote all his time to research and the development of his ideas.

He then became interested in developing a system of telegraphy by which musical tones could be transmitted and used for increasing the number of messages that could be sent simultaneously over the same wire. He patented the system in 1875. This work led him to the notion that the human voice could be transmitted. On February 14, 1876, he filed a caveat, or confidential report, on just such an invention with the U.S. Patent Office. Just a few hours previously, however, Bell had filed a patent application for the telephone.

In his famous experiment with voice transmission Bell had used a transmitter similar to one already developed by Gray, but Bell did not mention this device in his application. Bell also employed an electromagnet-metal diaphragm of the type previously developed and used by Gray. After the Western Union Telegraph Company acquired Bell's and Gray's patents, the long infringement contest began. Apparently, Bell was the first to transmit the human voice, but he used equipment developed by Gray. Nevertheless, Bell's patent was upheld.

Another of Gray's important inventions was the TelAutograph, which he patented in 1888 and 1891. This instrument transmitted facsimile writing between distant points and was used extensively by banks and railroad stations. In 1893 he organized the first International Electrical Congress for the World's Columbian Exposition.

Gray wrote many articles for technical journals and authored two books. He was decorated by the government of France and received several honorary degrees from U.S. institutions of higher education. While conducting experiments on underwater communications with ships, he died suddenly at Newtonville, Massachusetts.

GRIGNARD, FRANÇOIS AUGUSTE VICTOR (1871–1935)

A share of the 1912 Nobel Prize in chemistry was awarded to François Auguste Victor Grignard for his discovery of the versatile organic compounds now known as Grignard reagents. The

Victor Grignard

co-winner was another French chemist, Paul Sabatier. By using diethyl ether as a solvent in preparing combinations of magnesium with chlorine, bromine, or iodine (organic halides), Grignard made his important contribution to organic chemistry. The compounds are widely used in organic and organometallic synthesis because of their high chemical reactivity. A typical reaction is the formation of ethylphenyl carbinol from benzaldehyde and ethylmagnesium bromide. (*See* Paul Sabatier.)

Grignard, whose father was a sailmaker, was born in Cherbourg, France. He went to the University of Lyons with the intention of becoming a teacher of mathematics, but he turned to organic chemistry. Announcement of the Grignard reagents in 1900 generated a flurry of research and publication on the subject. Grignard obtained a doctor's degree in 1901 by presenting his work on the synthesis of acids, alcohols, and hydrocarbons. Most of his career thereafter was spent following up the implications of his discovery.

He became professor of organic chemistry at the University of Nancy in 1910. During World War I, Grignard was placed in chemical war work. He developed methods for detecting mustard gas and for preparing phosgene gas. After the war Grignard went to the University of Lyons as professor of organic chemistry and remained there for the rest of his life. In 1926 he was elected to the French Academy of Sciences.

GUERICKE, OTTO VON (1602–1686)

The seventeenth-century German natural philosopher Otto von Guericke invented the first air pump and the first frictional generator of electricity. He is remembered especially for the flair of his demonstrations of air pressure.

Guericke was born at Magdeburg in Prussian Saxony. He studied law and mathematics in his youth and traveled in France and England before taking the position of engineer for the city of Erfurt, Germany. Returning [illegible] Magdeburg in 1627, he entered pol[illegible]nd served as an alderman. When th[illegible] was destroyed in 1631 during a [illegible] battle of the Thirty Years' War, [illegible]ke escaped and served for a time i[illegible] Swedish army, which was engaged i[illegible] conflict in Germany. In 1646 he returned to Magdeburg and became its mayor, holding office until 1681, when he retired to Hamburg.

Scientific pursuits—pneumatics in particular—filled the leisure time of Guericke. His attempts to settle the old question of whether there is such a thing as a vacuum led to his invention of the air pump in 1650. It consisted o[illegible]linder, piston, and intake and di[illegible]ge valves; the joints were sealed by immersing them in water. Guericke made [illegible] of such a pump in 1654 in his celeb[illegible] demonstration of air pressure before the Reichstag at Regensburg, showing [illegible] teams of horses could not separate th[illegible]o halves of an evacuated hollow cop[illegible]phere. In other experiments he prove[illegible]t, in a vacuum, sound does not trav[illegible]andles do not burn, and animals can[illegible] live.

By holding his hand against a rotating globe of sulfur, Gueri[illegible]e produced the first generator of elect[illegible]city. He noted a crackling sound and saw a glow of light around the ball of sulfur when it was rubbed in the dark, and noticed that objects attracted to the sulfur when it was rubbed were repelled once they had touched it. This friction machine initiated many experiments in the following years and led toward Benjamin Franklin's recognition in 1752 that the electric discharge is responsible for energizing the luminescence displayed during lightning.

GUILLAUME, CHARLES ÉDOUARD (1861–1938)

The Swiss physicist Charles Édouard Guillaume, who spent his entire career in the Bureau of International Weights and Measures, won the 1920 Nobel Prize in physics for his research on alloys of nickel and iron. He is remembered especially for invar, which he named for its nearly invariable character, regardless of temperature change.

Guillaume was born in Fleurier, Switzerland. His father was a watchmaker, and the boy's early interest was also in that field. He studied mathematics and physics at the Federal Institute of Technology at Zürich. After serving for a time as an army artillery officer, he obtained his doctorate in 1883 and went to work in the bureau as an assistant. By 1915 he had worked his way up to the directorship, which he held until his retirement in 1936.

Conscientiously, Guillaume worked to increase the precision of the standard measures. He searched for an inexpensive material from which to construct standards of length and mass. Platinum-iridium alloy was in use because it did not corrode, but it was expensive.

Early in his career Guillaume was involved with thermometry measures. In 1889 he published a work on precision thermometry that became a standard reference for metrologists. His research into the thermal expansion of standards of length led him to examine various alloys. He found in 1896 that a steel alloy containing about 30 percent nickel had a thermal expansion only half that of iron. This spurred his research on ferronickels and led to his discovery of invar, which resists contraction and expansion when subjected to changes in temperature. Invar is used in standard measures, balance wheels, clock pendulums, hairsprings, and precision instruments.

GULLSTRAND, ALLVAR (1862–1930)

For his studies on the diffraction of light by lenses applied to the eye, the Swedish ophthalmologist Allvar Gullstrand won the 1911 Nobel Prize in physiology or medicine. He made important contributions to the understanding of the eye's structure, function, and ailments.

Gullstrand, the son of a physician, was born in Landskrona, Sweden. He studied medicine at the universities of Uppsala and Stockholm in Sweden and at the University of Vienna, Austria. Gullstrand had a strong interest in physics, which led him to specialize in an area that combined physics with medicine. At the age of thirty-two he was appointed professor of ophthalmology at Uppsala, where he held the chair of physiology and physical optics from 1913 to 1927.

Hermann L. F. von Helmholtz had shown earlier that the refractive power of the lens of the eye is altered by changes in its surface curvature that are controlled by ciliary muscles; but Gullstrand demonstrated that the refractive power is only about two-thirds dependent on the surface curvature and that the other third is caused by factors that he called the "intracapsular mechanism of accommodation." (The capsule, a clear, elastic membrane, encloses the many sheets of fibers that make up the lens. The core of the lens is firmer than the rind, the relative softness of which allows the lens to change shape under slight force.)

Gullstrand developed a photographic method for locating a paralyzed optical muscle, improved ways for estimating astigmatism, and introduced spherical lenses for glasses to be worn following cataract operations. His research was furthered by his inventions. The best known of his diagnostic instruments is the slit lamp, which casts a thin beam of light on the area to be examined while leaving the rest of the eye in darkness.

GUTENBERG, JOHANN (1398?–1468)

Using movable pieces of metal type and a special press that he had perfected, the German metalworker and artisan Johann Gutenberg invented Western printing. Although he did not actually produce the first book, it was his invention that led to the printing of the famous forty-two line, or Gutenberg, Bible.

Gutenberg was born in Mainz, Hesse, Germany, but the exact date is not known. He studied to become a goldsmith and achieved great skill in that trade. In about 1428 his family was exiled for political reasons, and from about 1430 to 1444 he lived in Strasbourg, France, where he took on some partners in a metalworking venture, accepting money from them with the agreement that he would teach them his craft.

It is believed that it was during this period that he began experimenting with printing, which had been unknown until then. Books were being copied by hand, and because of the time and effort involved, they were very expensive. Only universities, churches, and the wealthy could afford to own them. The only other method of reproduction known at the time was the ancient practice of making impressions by the reverse transfer method, much like the rubber stamps used today.

At Mainz, Germany, in 1450, Johann Gutenberg set up his own shop to perfect his printing techniques; today a reconstruction of the workshop can be found at the museum there.

Returning to Mainz in 1450, Gutenberg set up his own shop to perfect his printing techniques. He took on Johann Fust as a partner and Peter Schoeffer as an employee. In 1455 Gutenberg was involved in a lawsuit instigated by Fust, who charged that he had not repaid a loan. The court ruled in favor of Fust and ordered Gutenberg to turn over his printing equipment to Fust, who then went into business with Schoeffer.

The first printed matter to come out of this association was a Bible in 1457, still considered a masterpiece. Only 300 copies were produced. It is held almost universally that the book was a result of Gutenberg's techniques, thus the name Gutenberg Bible. Later works to come from Fust and Schoeffer also are attributed to Gutenberg's type molds and press. No printed work bears Gutenberg's name, but the idea that he developed the first printing process is further substantiated by his contemporaries and by the fact that Fust and Schoeffer never denied that Gutenberg was responsible for their success.

Gutenberg's invention involved a series of small blocks cast from a special mold, each one representing a single letter or character, that could be assembled into words and secured into a page form. These blocks could then be reassembled into other words and new pages. Gutenberg developed his own metal alloy for making the type, his own ink, and his own printing press.

HABER, FRITZ (1868–1934)

The great German physical chemist Fritz Haber was the first to succeed in synthesizing ammonia from its elements, hydrogen and nitrogen. His process found application in peacetime and wartime uses alike. For accomplishing the direct synthesis of ammonia Haber was awarded the 1918 Nobel Prize in chemistry.

The need to produce nitrogen compounds from atmospheric nitrogen posed one of the major chemical problems during the early 1900s. The world's largest nitrate deposits were located in northern Chile, far from any industrial center. Also, there were fears that this supply of nitrates would one day be exhausted, and nitrates were essential to the production of fertilizers and explosives. The irony of the problem lay in the fact that the gas nitrogen makes up four-fifths of the Earth's atmosphere.

Understanding that it would be easy to obtain nitric acid from ammonia, Haber set himself to the task of synthesizing ammonia directly from hydrogen and nitrogen under high pressure and high temperature and with the use of a catalyst. He succeeded in 1909. Four years later Karl Bosch developed the technique, often referred to as the Haber-Bosch process, for producing ammonia cheaply on an industrial scale.

Fritz Haber

During World War I all nitrate shipments to Germany were cut off by the British navy. It was Haber's process that allowed Germany to continue the production of explosives. The principle of the Haber process also enabled Friedrich Bergius to develop his method of hydrogenating coal for the formation of organic compounds.

Haber engaged in a wide range of chemical research. He investigated the thermal decomposition of hydrocarbons and other areas of study essential to the understanding of the cracking process. He made outstanding contributions in the field of electrochemistry, including the electrolytic reduction of nitrobenzene. He developed the first general theory of electrochemical reduction and devised the glass electrode. Haber also made studies on the application of Max Planck's quantum theory to chemistry. Other subjects of his investigations were beryllium compounds, the problems of aluminum production, the separation of gases by centrifugal force, the optical analysis of gases, chain reactions in gases, and the mechanism of combustion.

Haber was born at Breslau, Germany (now Wroclaw, Poland), and educated at the universities of Berlin and Heidelberg. In 1891 he took his doctorate in organic chemistry at the Technische Hochschule in Berlin; but he chose to work in physical chemistry, a field in which he was largely self-taught. He was a professor of chemistry at the Technische Hochschule in Karlsruhe until 1911, when he accepted the post of director of the Kaiser Wilhelm Institute for Physical Chemistry and Electrochemistry at Berlin-Dahlem.

During World War I he was chief of Germany's chemical warfare services and instituted the use of poison gas. He also worked on defensive measures against poison-gas attacks and had some responsibility for the supply of raw materials for the war ef[illegible]rt. After the war he was involved in [illegible] unsuccessful attempt to reclaim g[illegible] rom the sea. He envisioned this gol[illegible]amation project as a way to pay off [illegible]many's war debt.

Haber, a Jew, [illegible] extremely patriotic German a[illegible]refore suffered heartbreaking disa[illegible]ment after Hitler came to power [illegible]33, because of the anti-Semitic p[illegible] of the Nazi regime, Haber resig[illegible]om the Kaiser Wilhelm Institute [illegible]went into exile. He spent a few m[illegible] the Cavendish Laboratory at Ca[illegible] England, but finally went to Bas[illegible]tzerland, so that he could be clo[illegible] his homeland. While at Basel h[illegible]red a heart attack and died.

Among the hon[illegible]accorded Haber was the Rumford M[illegible]al of the Royal Society. He was als[illegible] honorary fellow of the Chemical S[illegible] of London.

HAECKEL, ERNST H[illegible]CH (1834–1919)

The German zo[illegible] Ernst Heinrich Haeckel is known [illegible] early adoption of Charles Darwin[illegible]s on evolution and was largely r[illegible]le for the dissemination and a[illegible] of the doctrine in Germany. [illegible]borate evolutionary relationshi[illegible] constructed, however, were bas[illegible] on fancy than on fact.

Haeckel, a native [illegible]tsdam, studied medicine and scien[illegible] Würzburg, Berlin, and Vienna. In 1[illegible] became a professor of comparativ[illegible]tomy and director of the zoological institute of the University of Jena, where a chair of zoology was created for him in 1865. He spent the rest of his life in that post.

The biogenetic law and the gastraea theory were two of Haeckel's extreme notions that subsequently were disproved. The biogenetic law stated that ontogeny (the course of development of an individual organism) repeats phylogeny (the evolution of a genetically related group of organisms, distinguished from the development of the individual organism). Later it was pointed out that ontogeny does not repeat phylogeny; it creates it. In his gastraea theory Haeckel built a genealogical tree of the animal kingdom showing that all passed through a gastrula (early metazoan embryo) stage in their development and tracing the metazoa back to a common ancestor, the hypothetical gastraea.

Haeckel was a prolific writer; and of his many publications, *Die systematische Phylogenie* (1894) is considered among the best. He was also a talented artist; and some of the illustrations in his works are excellent, wh[illegible] others tend to be as overimaginativ[illegible] [illegible]me of his theories.

HAHN, OTTO [illegible]–1968)

The Germar [illegible] nist Otto Hahn was the first to sp[illegible] atom and thus discovered nucle[illegible]n. His discovery led to the releas[illegible]clear energy, which was first used [illegible]itary purposes in the form of the a[illegible] bomb and later for such peaceful [illegible]s generating electric power. For hi[illegible]k in the area of nuclear fission H[illegible]as awarded the 1944 Nobel Prize i[illegible]istry.

Hahn was b[illegible] Frankfurt am Main, Germany. He [illegible] educated at the universities of M[illegible]g and Munich and in 1901 receive[illegible] doctorate from Marburg. In 1904 [illegible]ent to London to work with Sir Will[illegible] Ramsay. Then in 1905 he assisted Si[illegible]nest Rutherford at McGill Universit[illegible] Montreal, Quebec. He returned to [illegible]nany in 1906 and for some time wa[illegible] leading German radiochemist.

Hahn worl[illegible] the chemistry laboratory of the [illegible]versity of Berlin until 1912, when [illegible]oined the staff of the Kaiser Wilh[illegible] Institute for Chemistry at Berlin-Da[illegible] From 1928 to 1944 he served as di[illegible]r of the institute.

Most of [illegible]'s research was conducted in as[illegible]tion with the Austrian-Swedish phy[illegible]st Lise Meitner. In 1917 they detect[illegible] radiothorium, mesothorium, and pr[illegible]tinium, and in 1921, nuclear isomers. Meitner was forced to flee Germany in 1938 because of the Nazi regime, and thereafter Hahn was assisted by Fritz Strassman.

During the mid-1930s Hahn had begun experimenting with the bombardment of uranium with neutrons and had discovered a number of transuranium elements. In 1938, during one of these irradiation experiments, Hahn and Strassman detected a highly radioactive substance, which they assumed was radium. Further chemical analysis, however, led them to the conclusion that the radioactive substance was barium, which meant

Otto Hahn

that the uranium atom had been split in two.

The idea of uranium fission seemed so unlikely that Hahn was reluctant to publish the results of this experiment. It was Meitner, in exile in Sweden, who first published the report on nuclear fission. Soon afterward Hahn announced that the second part of the uranium fission was the gas krypton. Hahn and Strassman hypothesized that additional neutrons were released by the fission of uranium and therefore there existed the possibility of a chain reaction that could release the energy of the atomic nucleus.

The Nazi government failed to recognize the importance of Hahn's discovery.

Although relatively simple at first, Otto Hahn's experiments ultimately revealed a number of transuranium elements and led to nuclear fission and the release of nuclear energy.

Further investigations were carried out in the United States, however, and the immediate result of this extended research was the development of the atomic bomb. Because of his discovery of nuclear fission Hahn felt personally responsible for the destruction caused by the bomb and was disturbed even to the point of contemplating suicide.

Hahn remained firmly opposed to all nuclear weapons and refused to cooperate in their development or manufacture. After World War II, from 1946 to 1960, he was president of the Max Planck Society of Göttingen, Germany.

HALDANE FAMILY

Among the notable members of the distinguished Haldane family of Scotland were two outstanding scientists, John Scott Haldane (1860–1936) and his son John Burdon Sanderson Haldane (1892–1964). Father and son alike made valuable contributions to the science of physiology, and the younger Haldane was also a noted geneticist and biometrician.

The elder Haldane was born in Edinburgh, Scotland, and studied at Edinburgh University and at the University of Jena in Germany. After graduating in medicine from Edinburgh in 1884, he was a demonstrator in physiology at University College, Dundee, and from 1897 to 1907 at Oxford, where he then became a reader in physiology. In 1912 he was appointed director of a mining research laboratory. When it became affiliated with the University of Birmingham in 1921, he stayed on as director and was made honorary professor of mining at the university.

He lectured at Yale University in 1916, at Glasgow University, Scotland, in 1927–1928, and at Dublin University, Ireland, in 1930. From 1924 to 1928 he served as president of Britain's Institution of Mining Engineers. He was elected a fellow of the Royal Society in 1897 and was awarded the Royal Medal in 1916 and the Copley Medal in 1934.

The most important research conducted by the elder Haldane involved respiration. During the 1890s he made studies for the government on deaths and diseases caused by poor ventilation in mines and in 1896 reported that most deaths in coal-mine explosions were caused by carbon monoxide. His work in this area led to improved mine-safety conditions.

In 1905 he made another important

addition to knowledge about respiration. Since 1894 he had been working on ways to estimate gases in the blood, and in the course of his research he found that breathing is automatically regulated to keep a constant partial pressure of carbon dioxide in the alveoli. This led to his conclusion that the regulation of breathing is determined by the effect of the tension of carbon dioxide on the respiratory center of the brain.

To study the effects of low barometric pressure, he led an expedition to Pike's Peak, Colorado, in 1911. He also developed stage decompression for bringing deep-sea divers to the surface fairly rapidly and at the same time preventing nitrogen bubbles from forming in their tissues.

The younger Haldane was born in Oxford, England. He became acquainted with research and scientific techniques at an early age, for when he was only about eight years old he began assisting his father. He was educated at Eton and at New College, Oxford. In 1919, after having served with the Black Watch Regiment during World War I, he became a fellow at New College, Oxford, and three years later a reader in biochemistry at Cambridge, where he remained ten years. During 1932 he was a visiting professor at the University of California. The following year he was appointed professor of genetics at London University, and in 1937, professor of biometry at University College, London.

During the 1930s Haldane announced his sympathy for Marxism and for several years was active as editor of the *Daily Worker*, a Communist paper. Eventually, however, he became disillusioned with the existing official party line and with the prominence of the controversial biologist Trofim Denisovich Lysenko. He also found certain policies of the British government intolerable, and in 1957 he resigned from University College and went to India.

There he became a member of the Biochemistry Research Unit at Calcutta. In 1961 he was naturalized as an Indian citizen. From 1962 until his death he was director of the Genetics and Biometry Laboratory of the government of the state of Orissa at Bhubaneswar.

He made several major contributions in the areas of population genetics and enzyme kinetics. Applying mathematical analysis to the study of genetics, he demonstrated the relationship of genetics to evolution. He also did studies on mutation rates—especially those relating to hemophilia and color blindness—stemming from harmful dominant or sex-linked genes as they occur in natural populations.

For his physiological studies he often used himself as the subject of his experiments. On one occasion, while attempting to prove that sunstroke is caused by overheating of the brain and spinal cord, he spent hours in the sun for several consecutive days. Although this did not bring on a sunstroke, it did give him a severe sunburn.

The younger Haldane was also a great popularizer of science and wrote many volumes for professionals and laymen alike. *Animal Biology* (1927) was written with J. S. Huxley. His Marxist tendencies are reflected in some of his books, the most important of which are *Possible Worlds* (1927), *Science and Ethics* (1928), *Enzymes* (1930), *The Causes of Evolution* (1933), *Fact and Faith* (1934), *Heredity and Politics* (1938), *The Marxist Philosophy and the Sciences* (1938), *Science and Everyday Life* (1939), *New Paths in Genetics* (1941), *Science Advances* (1947), and *The Biochemistry of Genetics* (1954).

Although he held political beliefs unpopular in the Western world, he was honored by governments and by professional organizations. In 1932 he was elected a fellow of the Royal Society and in 1953 was awarded its Darwin Medal. He received the Kimber Genetics Award of the U.S. National Academy of Sciences in 1961 and became a foreign associate of the academy in 1964.

HALE, GEORGE ELLERY (1868–1938)

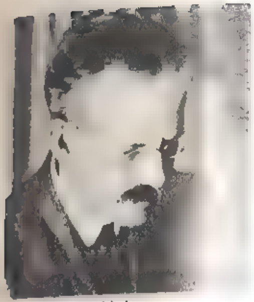
Toward the middle of the nineteenth century, astronomy had undergone a complete revolution. Because of the work of a few scientists, the study of the physical phenomena of celestial bodies was gaining ground over the classical aim of determining the position of the stars and the movement of the planets. The U.S. astronomer George E. Hale was a student of solar physics who became known for his development of great astronomical instruments. Because of him astrophysics came of age. It can be said that from the end of the last century to today all astronomical instruments that held or hold the record for size and conception were planned and conceived by him.

Hale was born in Chicago, Illinois, the son of a wealthy manufacturer, and early showed an interest in astronomy. While completing his higher studies at the Massachusetts Institute of Technology, Cambridge, he built his own private astronomical observatory. In 1889–1890 he carried out research work at the larger Harvard College Observatory.

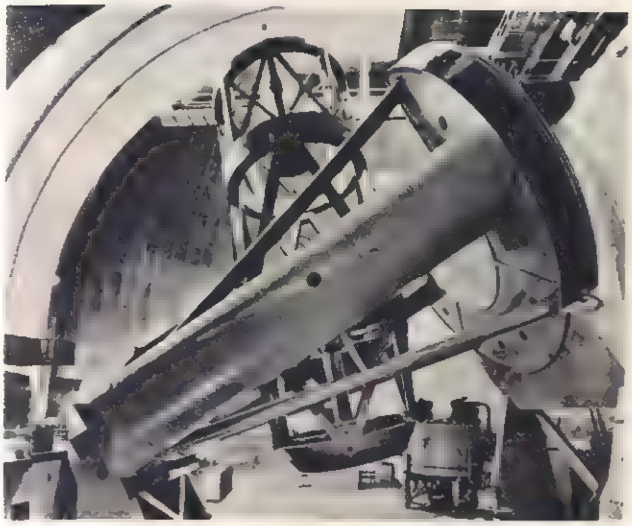
His research revealed descriptive astronomy as a dead science to him, destined to decline still further or at least remain static. He became convinced that astrophysics was the science of the future and that new instruments, suitable for astrophysical research, would lead to important discove[illegible] in a short time; but he felt that t[illegible]w astronomers were devoting them[illegible]es to this new science. With the [illegible]ion of gaining new converts to as[illegible]sics, therefore, he moved to Europ[illegible]re he lived and did research for a y[illegible]rimarily in Berlin, Germany. His f[illegible]urpose was to convince his Europ[illegible]lleagues of the need for publishing [illegible]gazine devoted entirely to the new s[illegible]. Such a magazine would make co[illegible]ration between the scientists of diffe[illegible] countries easier and facilitate the ex[illegible]nge of ideas on an international lev[illegible]s a result of his efforts the *Astroph[illegible]al Journal* was born in 1895 and [illegible]came the most important periodical on astrophysics in the world.

Meanwhile, in 18[illegible]891, he had organized the Kenw[illegible] Observatory in Chicago and while [illegible] had invented the spectroheliograp[illegible]nstrument that photographs the sun [illegible]monochromatic light, revealing the c[illegible]cteristics of its surface. For many ye[illegible] Hale owed his fame to this device. H[illegible]d it systematically to study the p[illegible]omena of the solar photosphere, co[illegible]ting more discoveries in this way [illegible]r physics than had been made in all [illegible]preceding centuries. In particular h[illegible]ticed the relationship between suns[illegible] flocculi, flares, and prominences.

In 1892 one of his patrons, U.S. financier Charles Tyson Yerkes, gave Hale the funds necessary for setting up a large observatory on the shore of Lake Geneva, at Williams Bay, Wisconsin, about ninety-five miles north of Chicago. With the optical techniques available at that time, a refractor, with its lens objective, was much easier to make than a reflector, the most important part of which was a parabolic mirror that was extremely difficult to make, and so the largest refractor in the world was built. The uniqueness of the Yerkes Observatory lay in the fact that besides the domes for the telescopes, there were laboratories for the study of solar physics and for the purpose of reproducing phenomena similar to those observed on the sun. Using the spectroheliograph that was built in the observatory laboratories, Hale was able for the first time to study



George Hale



In 1928, at Mount mar, California, George Hale started the taking that resulted in the largest telesc n the world, with a mirror about 200 inches in diameter. When it was completed twenty years later—ten years after Hale's death—it was named in his honor.

the distributio vapors at different heights on the r surface.

When it soo ecame apparent that the study of r and stellar physics would bear e better results if the instruments w still more powerful and placed in a re appropriate place, far from city nts and mists, Hale presided over different phases of construction of new complex that was planned as th gest and most important in the w He obtained the finances for th w undertaking from industrialist a philanthropist Andrew Carnegie and en looked for the site that would be ost suitable, traveling and personally examining atmospheric turbulence with scrupulous measurements. Mount Wilson, 5,700 feet above sea level, and near Pasadena, California, was chosen. The number of hours favorable for astronomical observation was three times greater there than at Chicago.

Two solar towers (60 and 150 feet high) were built at Mount Wilson. These made it possible to use spectroheliographs of large focal lengths and later helped Hale complete his important studies on sunspots and on the sun's general magnetic field. Then a reflecting telescope with a mirror of about 60 inches in diameter was built, and later, between 1918 and 1920, a second one, with a mirror of about 100 inches in diameter, was installed.

From 1904 to 1923 Hale was director of the Mount Wilson Observatory; those were, if not the most intense years of his life, certainly the most hard-working and fatiguing ones, because he not only had to find time for research but also had to plan, direct, and develop the observatory and its huge personnel. He served as secretary of the National Academy of Sciences and as a member of the Pasadena City Planning Commission. He also helped organize the Huntington Library and Art Gallery in San Marino, California, and the National Research Council.

Research work was no less productive because of this, however; at Mount Wilson he had gathered researchers of world fame, attracted by both the interest of such a group of scientists and the fact that the most powerful means of research in the world were available. He and his colleagues discovered a way to measure the temperature inside sunspots; and a little later he also discovered that they were sites of intense magnetic fields. Meanwhile, he was becoming slowly weaker, more because of age than from his untiring efforts, and this forced him to slow down his rhythm of work. Thanks to him, however, the California Institute of Technology was founded at Pasadena. This became a sort of instrumentation laboratory for the Mount Wilson Observatory. Hale invented instruments and then distributed them to various observatories so that research work could be done together. Robert Millikan was called to head the new laboratory.

A few years after making the 100-inch telescope, he had decided the time was ripe for a still larger instrument, no less than double the size, and in 1928 he began making the largest telescope in the world, with a mirror about 200 inches in diameter. Hale began the undertaking by looking for a new site to place another observatory because extraordinary development of the cities lying below Mount Wilson (Pasadena, Los Angeles, Hollywood) had noticeably worsened visibility conditions, which once had been good. The new site chosen, Mount Palomar, was 6,138 feet above sea level and about 100 miles from Mount Wilson.

The gigantic project of constructing the new reflector occupied technicians for twenty years. The most difficult part was the fusion of the large block of glass for the telescope, which risked the failure of the whole undertaking more than once. When it was finally completed, ten years after Hale's death, the enormous instrument was named in his honor.

Hale was awarded many honors in his lifetime and was elected to most of the world's academies of science. His many books include *The Study of Stellar Evolution* (1908), *The Depths of the Universe* (1924), and *Signals from the Stars* (1931).

HALLEY, EDMUND (1656–1742)

Through the influence of King Charles II, the English mathematician and astronomer Edmund Halley secured an introduction to the East India Company and set sail on one of its ships to the island of Saint Helena in the South Atlantic—the island made famous many years later as the last home of Napoleon Bonaparte; his objective: to catalog the stars of the Southern Hemisphere. While yet a student at Saint Paul's School, London, and Queen's College, Oxford, he had been an experienced astronomical observer and, finding errors in the then existing star tables, had become convinced of the necessity to the progress of astronomy of establishing the positions of the stars more accurately. In the two years (1676–1678) that he spent on Saint Helena, he set up the first observatory of the Southern Hemisphere and recorded more than 300 southern stars, published as *Catalogus stellarum Australium* in 1679. This publication, the first of its kind, established his reputation.

Halley's greatest contribution to astronomy, however, was his study of comets. Fascinated by the seemingly erratic motions of the comets, he applied himself to the solution of their mystery. With the help of his friend Sir Isaac Newton—whose *Principia* he published at his own expense in 1687—he worked out the paths of numerous comets. A comet of particular interest to him was that of 1682, which he had observed personally. In 1705, after compiling the movements of twenty-four comets, he was struck with the similarity of the

comet of 1682 with those of 1456, 1531, and 1607. Noticing that these comets had appeared at intervals of seventy-five or seventy-six years, he concluded that these four were one and the same comet that traveled about the sun in a very elongated orbit and was visible only when relatively close to the Earth, and correctly predicted its return in 1758. This prediction was the first application of Newton's laws of motion. The comet has been known as Halley's comet ever since, and, as expected, it appeared again in 1835 and 1910.

Pursuing his interest in astronomy still further, Halley, in 1718, observed that the stars Sirius, Procyon, and Arcturus had changed their positions markedly since the time of the ancient Greeks, which led him to the first determination of stellar proper motion. Contrary to the general belief of the time that the fixed stars never change their relative positions, Halley concluded that they have motions of their own but that these are perceptible only over long periods of time because of their great distances from the Earth.

Halley's other contributions to the study of astronomy included the discovery of the magnetic origin of the aurora borealis, and the secular acceleration of the moon's mean motion. The latter discovery was the result of his careful observations, while astronomer royal, beginning in 1720, of the moon through the eighteen-year revolution of its nodes. His suggestion, in 1679 and again in 1716, of determining the solar parallax by means of the transit of Venus greatly reduced the margin of error involved in its calculation.

In addition to astronomy, Halley was also a pioneer in many other scientific areas. He was the first to use graphical means of depicting on maps the geographical distribution of the Earth's physical features. In 1686 he published the first map of the winds on the surface of the Earth. The first meteorological chart appeared in 1688, and the first magnetic one, in 1701. His *Breslau Table of Mortality* (1693) was one of the first attempts to found tables of annuities on a basis of fact. As commander of the war sloop *Paramour Pink* 1698–1700, he headed the first sea voyage undertaken for purely scientific purposes. In 1701, during a study of tides in the English Channel, he was again at the helm of the *Paramour Pink*. He was the first to suggest, in 1715, that the sea was salty because of the deposits from the rivers.

His scientific endeavors and investigations brought him many academic honors. For his work in cataloging the southern stars, he was granted a master's degree by royal mandate and made a fellow of the Royal Society. In 1703 he was appointed Savilian Professor of Geometry at Oxford.

HAMILTON, SIR WILLIAM ROWAN (1805–1865)

When only in his early teens William Rowan Hamilton was something of a linguistic genius, already knowing more than a dozen languages. It was as a mathematician, however, that he was to become famous, especially for his invention of quaternions, which are hypercomplex numbers, and for his principle of varying action, known also as Hamilton's principle, which is useful in both optics and mechanics and found throughout modern theoretical physics.

Hamilton was born in Dublin, Ireland, the son of a lawyer. Not only was he well versed in linguistics, but by the age of seventeen he was also one of the greatest living mathematicians. At Trinity College, Dublin, he was so brilliant that in 1827, even without a degree, he was appointed Andrews Professor of Astronomy. In that same year he was also made astronomer royal. The rest of his life was spent studying mathematics at an observatory near Dublin, the last twenty years as a recluse and alcoholic.

While working on quaternions in the early 1840s, Hamilton discovered that, contrary to what seemed an eternal truth at the time, the commutative law of multiplication need not necessarily hold; that is, $a \times b$ does not always equal $b \times a$; in fact, he found that when a and b are quaternions, $b \times a$ equals $-a \times b$. Hamilton showed that there can be more than one algebra, much the same as there can be more than one geometry. Algebra, like geometry, is based on a certain set of rules; and when the rules change, the structure changes. His discovery of noncommunicative algebra was to be of fundamental importance many years later in the development of quantum mechanics and in understanding the internal structure of an atom.

In addition to his work with quaternions, Hamilton also originated the hodograph and investigated optical paths, or the paths of light, predicting in his *Theory of Systems of Rays* (1828) the existence of conical refraction. His other writings include *On a General Method in Dynamics* (1834–1835), of great importance to the quantum theory, and *Elements of Quaternions*, his last book, which was published posthumously in 1866.

For his accomplishments Hamilton was knighted in 1835, at the height of his career. He was also honored by many foreign societies, such as the Saint Petersburg Academy and the National Academy of Sciences of America, which made him the first foreign member shortly before his death.

HARDEN, SIR ARTHUR (1865–1940)

The lifework of Sir Arthur Harden, English biochemist, advanced the understanding of intermediary metabolism—now an important branch of biochemistry. For his research on sugar fermentation and the attendant enzyme action, he shared the 1929 Nobel Prize in chemistry with Hans von Euler-Chelpin. (*See* Hans Karl August Simon von Euler-Chelpin.)

Harden saw that when he placed a yeast extract inside a bag made of semipermeable membrane and placed that bag in pure water, the yeast enzyme could no longer ferment sugar. If he then added the water outside the bag to the material inside, the yeast's activity resumed. He found, thus, that the yeast enzyme consisted of one small-molecular part and one large-molecular part, because in this process, known as dialysis, small molecules in the extract pass through the membrane while large molecules remain. He learned further that when the material within the dialyzing bag was boiled, activity was lost even with the addition of the outer water. From this reaction Harden deduced that the large portion of the molecule was protein and the small molecule, which survived boiling, was not. This small nonprotein molecule that is necessary for activating the protein enzyme was the first known coenzyme.

For more than thirty years Harden made studies of the fermentation of sugar by expressed yeast juice. His search for compounds formed as intermediates in the course of the chemical reactions emphasized the importance of phosphate groups in biochemistry.

Harden was born in Manchester, England, where he studied chemistry at Owens College (later the Victoria University of Manchester). He went to the University of Erlangen in Germany for further study and received his doctorate there in 1888. After teaching at Owens College and writing textbooks for the next nine years, Harden became interested in the discovery by the German chemist Eduard Buchner that alcoholic fermentation can proceed without the presence of living cells. In 1897 Harden

joined the Jenner Institute of Preventive Medicine (later the Lister Institute) in London and started his own research on fermentation. From 1907 until his retirement in 193[illegible] [illegible] headed the Department of Biochen[illegible]

His best-known [illegible] ten work, *Alcoholic Fermentation*, [illegible]d in four editions. From 1913 to [illegible] e served as joint editor of *The [illegible]mical Journal*. He was elected a fe[illegible]f the Royal Society of London in 1[illegible] d was awarded its Davy Medal in [illegible] The following year he was knight[illegible] is achievements.

HARDY, GODF[illegible] HAROLD
(1877–1947)

One of the l[illegible]g mathematicians of his time was [illegible] Englishman Godfrey Hardy. He is [illegible]ially known for his work in anal[illegible] n which he wrote a number of pa[illegible] that he contributed to mathemati[illegible]rnals.

Hardy was [illegible] in Cranleigh, Surrey, England. He [illegible]ved his higher education at Winch[illegible] College and at Trinity College, C[illegible]ridge, where he was a Prize fellov[illegible]n 1900 to 1906 and a lecturer in m[illegible]matics from 1906 to 1919, when [illegible]vas appointed to the Savilian Cha[illegible] Geometry at Oxford University. I[illegible] he became Sadleirian Professor of [illegible] Mathematics at Cambridge, a pos[illegible] that he held until his retirement in [illegible]2

In 1910 h[illegible] elected a fellow of the Royal Societ[illegible] He received its Royal Medal in 19[illegible] its Sylvester Medal in 1940, and its [illegible]pley Medal in 1947.

HARRISON, JOHN (1693–1776)

In the eighteenth century John Harrison, a self-taught British horologist, invented the first practical marine chronometer. Not until the advent of radio communications was his invention displaced. One of his clocks was off by only less than a minute after five months at sea—a better record than any clock of the time achieved on land.

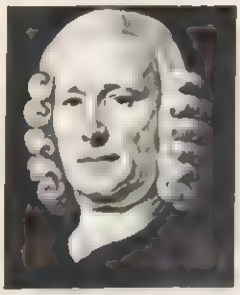
Britain was still concerned in the eighteenth century with the problem of determining longitude at sea, the same problem that had led to the founding, in 1675, of the Royal Greenwich Observatory. Latitude was determined by astronomical observations, but the fixing of longitude depended upon knowing the local time relative to that of Greenwich, England. If a navigator knew the Greenwich time wherever he might be, he could note the difference between local time and Greenwich time (established astronomically) and proceed to calculate the longitude. This method, however, required a timepiece that would run accurately aboard ship on the high seas.

In 1714 the British government offered prizes of up to £20,000 for a ship's chronometer. Harrison, a native of Yorkshire, began in 1728 to build a series of five clocks. He took his early designs to London, where he showed them to George Graham, a leading horologist. Graham saw promise in the designs and loaned Harrison money to continue his work. The first four of Harrison's chronometers were heavy, complicated, and costly, though each was better than its predecessor. The fifth was no larger than a watch, but it was the best of all. Every one of the five met the conditions of the government award.

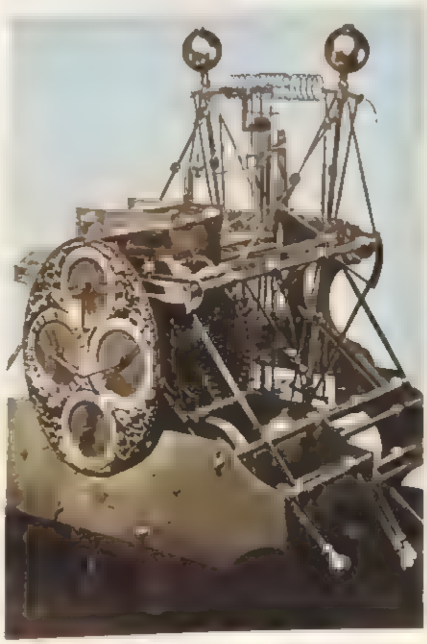
The British Parliament delayed paying Harrison any prize money. Although Harrison met its demands for ever greater perfection, he received only small sums. Finally, the interest of King George III was elicited, and Harrison received an award of £5,000 in 1773.

Among Harrison's inventions was a pendulum so constructed that the overall length did not vary with temperature changes, thus assuring an unaltered beat. He also invented a device that kept the time undisturbed while a clock was being wound. Harrison received the Copley Medal of the Royal Society in 1749.

John Harrison



Beginning in 1728, the British horologist John Harrison built a series of clocks to help determine longitude at sea and thereby invented the first practical ship's chronometer.



HARTLINE, HALDAN KEFFER
(1903–)

For research into the microelectrical mechanics of vision, the U.S. biophysicist Haldan Hartline shared the 1967 Nobel Prize in physiology or medicine with two other scientists—researchers Ragnar Granit and George Wald. Hartline recorded the electronic reactions of optic nerve fibers to light and made discoveries that led to the basic understanding of vision. The Nobel citation noted that his work explains how the eye is able to differentiate between form and movement. (*See* Ragnar Arthur Granit; George Wald.)

Hartline was born in Bloomsburg, Pennsylvania, and took his bachelor's degree in 1923 at Lafayette College, Easton. After receiving his doctorate in 1927 at Johns Hopkins University, Baltimore, he became a National Research Council fellow for two years. From 1929 to 1931, while on a traveling research scholarship, he pursued his studies further at the universities of Leipzig and Munich in Germany. His teaching career included Cornell University Medical College in New York, the University of Pennsylvania, Johns Hopkins, where from 1949 to 1953 he taught and chaired the Jenkins Department of Biophysics, and Rockefeller University in New York City. For his work he won the William H. Howell Award in Physiology, the Warren Medal, and the Albert A. Michelson Award.

Haldan Hartline

HARVEY, WILLIAM (1578–1657)

By meticulous experiments the English physician William Harvey discovered how blood circulates through the

body. His conclusions, published early in the seventeenth century, are the foundation of modern physiology.

When Harvey was a youth, medical men still held the view of Galen, first-century Greek physician, who believed that blood passes from one side of the heart to the other through microscopic pores. It was not suspected that the heart is a pump or that blood travels in a continuous stream through the body and back to its source. Harvey was ridiculed when he dared to contradict ideas that had prevailed for more than 1,000 years, but he lived to see his theory acclaimed.

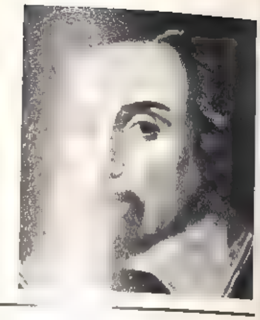
Harvey was born at Folkestone, Kent, England. A son of well-to-do farmers, he was sent to Canterbury School at the age of ten. Later he studied at Caius College, Cambridge, and went from there to Padua, Italy, which at that time had one of the best medical schools in the world. There he was a student of Fabricius ab Aquapendente, who had discovered the valves in veins but did not understand their significance. It was for Harvey to discover that the valves kept the blood flowing in one direction.

After receiving his medical degree in 1602, Harvey returned to London. In 1604 he married Elizabeth Browne, whose father was physician to Queen Elizabeth I and to her successor, James I. Elizabeth Harvey died childless in 1645.

Harvey was admitted as a fellow of the Royal College of Physicians in 1607. He became physician to Saint Bartholomew's Hospital in 1609. In 1616 he began a series of lectures at the College of Physicians in which he first made known his views on circulation. Although he preferred research to medical practice, Harvey counted eminent persons among his patients. They included Francis Bacon, King James I, and Charles I, who was captivated by Harvey's experiments and provided him with animals from the royal deer parks.

Harvey's outstanding work, *An Anatomical Treatise on the Movement of the Heart and Blood in Animals*, was published in 162[illegible] clear, concise, and well-documen[illegible]tle volume is probably the sing[illegible]test classic in the history of phy[illegible] After years of experiments, obser[illegible], and analysis, Harvey showed tha[illegible]eart is a pump that works by mu[illegible]ction and that blood does not eb[illegible] flow back and forth in the vesse[illegible] travels in one direction from th[illegible]t and back to the heart. His trea[illegible]vas incomplete on one point only. [illegible]gh Harvey had deduced the exist[illegible] of capillaries, through which the [illegible]d passes from the arteries to the [illegible] he had never seen them. Thirty [illegible] later the great anatomist Marcello [illegible]ighi observed capillaries through [illegible]s of a microscope; and four yea[illegible]r Harvey had died, he described [illegible]ry circulation, proving Harvey's th[illegible]

After the publica[illegible]f his treatise, Harvey was engage[illegible]efly in an investigation of the ge[illegible]on of animals, a subject in which [illegible]ius had interested him; and in 16[illegible] observations on embryonic growt[illegible]re published. He had retired five ye[illegible] earlier, at the age of sixty-eight. By [illegible] his theory of blood circulation was generally accepted by the most prominent anatomists of his time, and he was known and honored throughout Europe. In 1654 Harvey was elected president of the College of Physicians but declined the honor, preferring to live quietly.



William Harvey

As was customary at the time, William Harvey's coat of arms, together with the indication of his nationality as English, was painted on a vault of the portico in the central courtyard of the University of Padua, where he earned his medical degree in 1602.

HASSEL, ODD (1897–)

The 1969 Nobel Prize in chemistry was shared by Odd Hassel, professor emeritus of the University of Oslo, and British chemist Derek Barton of London's Imperial College of Science and Technology. The men were honored for their work in three-dimensional conformation analysis in studying how complex molecules are shaped. (*See* Derek Harold Richard Barton.)

During the 1930s and 1940s Hassel studied cyclohexane, a hydrocarbon with a zigzag chain of six carbon atoms that form a ring. His research showed how the atoms orient themselves with one another.

Odd Hassel

Hassel was b[illegible] Oslo, Norway, and studied at th[illegible]versity there. After earning his do[illegible]ate at Berlin University in 1924, h[illegible]urned to the University of Oslo t[illegible]ch and from 1934 to 1964 was dire[illegible] of physical chemistry. Like many oth[illegible]embers of the university faculty, H[illegible]l was imprisoned for two years in a[illegible]al camp outside Oslo during the N[illegible] occupation of Norway in World War [illegible] He was made an honorary fellow o[illegible] Chemical Society of London, cha[illegible]n of the Norwegian Chemical So[illegible] and a member of the Norwegian C[illegible]il for Science and Humanities.

HAWORTH, S[illegible]WALTER NORMAN
(1883–1950)

For his w[illegible] on carbohydrates and vitamin C, Si[illegible]alter Norman Haworth, British orga[illegible]hemist, shared the 1937 Nobel Priz[illegible] chemistry with Paul Karrer, a Sw[illegible] chemist. Haworth was responsible f[illegible] clarifying the structures of many com[illegible]ounds, including cellulose, glycogen, and starch. (*See* Paul Karrer.)

His long interest in sugars led Haworth to investigate vitamin C, which has a molecule somewhat similar chemically to that of sugar. In 1934 he announced that he and his colleagues had synthesized ascorbic acid (vitamin C). This accomplishment led to large-scale production of the vitamin. His later work helped coordinate problems in chemistry, physics, and biology relating to bacterial polysaccharides. Haworth's book *The Constitution of Sugars* (1929) became a standard work.

Haworth, a native of Chorley, Lancashire, England, graduated from Owens College at Manchester and received his doctorate from the University of Göttingen, Germany. In 1911 he became senior demonstrator in chemistry at Imperial College, London. From 1912 to 1920 he was a reader in chemistry at Saint Andrew's University, Scotland. With his reputation growing, he was appointed to a chair at King's College, Newcastle, which he occupied from 1920 to 1925, and to directorship of the chemistry department at Birmingham University, 1925 to 1948.

The Royal Society of London elected Haworth to fellowship in 1928 and awarded him its Davy Medal in 1934 and its Royal Medal in 1942. From 1944 to 1946 he was president of the Chemical Society, which had presented him with its Longstaff Medal in 1933. In 1945 he was asked to serve on the committee for advances in carbohydrate chemistry. He was honored with membership in many foreign academies and was knighted in 1947.

HEISENBERG, WERNER KARL
(1901–)

The German physicist Werner Karl Heisenberg profoundly influenced the development of modern physics by his investigations of atomic structure. He was awarded the 1932 Nobel Prize in physics for his work in quantum mechanics, the basic mathematical tool of nuclear physicists. Heisenberg is best known for his uncertainty principle, which is a theorem of quantum mechanics.

The principle, which he developed in 1927, holds that the exact position and momentum of a moving electron cannot be determined at the same time because the precise measuring of one precludes the accurate measurement of the other. For example, in order for the position of an electron to be determined, a ray of light having a short wavelength must strike the tiny electron. The high frequency and high energy of such a ray (gamma ray) actually change the velocity of the electron, making impossible the accurate measurement of its momentum (mass times velocity). Unlike other concepts of the quantum theory, Heisenberg's deals with the interactions of matter and radiation in terms of *observable* quantities—such as the frequencies, or colors, of light given off by atoms.

Heisenberg was born in Würzburg, where his father was a professor of Byzantine history. From his youth onward, Werner worked with some of the world's greatest physicists. At the University of Munich his teacher was Arnold Sommerfeld. After receiving his doctor's degree in 1923, Heisenberg worked as an assistant to Max Born at the University of Göttingen, where he was appointed a lecturer in 1924. Then for the next three years he studied with Niels Bohr in Denmark and laid the foundations for his theory of matrix mechanics, a branch of quantum mechanics.

In 1927, when he was not yet twenty-six years old, Heisenberg was appointed professor of theoretical physics at the University of Leipzig, Germany. He held that position until 1941. With his appointments that year as professor at the University of Berlin and director of the Kaiser Wilhelm Institute for Physics, later named the Max Planck Institute for Physics and Astrophysics, Heisenberg became head of the German program for atomic research. After World War II he moved to Göttingen in West Germany and became director of the Max Planck Institute for Physics there. Later he again took direction of the Berlin institute when it was moved to Munich.

Werner Heisenberg

Heisenberg was honored with membership in the scientific academies of Leipzig, Berlin, and Göttingen, as well as those of Oslo, Norway; Bucharest, Rumania; and Uppsala, Sweden. He was also a foreign member of the Royal Society of London.

HELMHOLTZ, HERMANN LUDWIG FERDINAND VON (1821–1894)

The nineteenth-century German scientist Hermann von Helmholtz is remarkable for his broad interests and accomplishments of lasting magnitude. Although he is best known for his theory of the conservation of energy, he also conducted epoch-making research in the field of physiology and made important contributions in dynamics and electricity.

Helmholtz was born in Potsdam, Prussia, and in 1838 entered Friedrich Wilhelm Medical Institute, the students of which attended lectures at the University of Berlin. There he was influenced by Johannes Peter Müller, the leading physiologist of his time. After graduation, Helmholtz practiced for several years as a military surgeon.

In 1849 Helmholtz was appointed professor of physiology at the University of Königsberg, in 1855 at Bonn, and in 1858 at Heidelberg. He became chairman of the physics department at the University of Berlin in 1871 and, in addition, later

accepted the directorship of the newly founded Physico-Technical Institute at Charlottenburg, near Berlin, holding both positions from 1877 until his death.

Physiology and physics were complementary in the productive scientific life

Hermann Helmholtz

of Helmholtz. A thesis he wrote in 1842 on the connection between nerve fibers and nerve cells was followed by a study of muscle action showing that animal heat is produced mainly by muscle contractions. This study of animal heat opened the way for his investigations into energy conservation. In 1847 he read his celebrated paper "On the Conservation of Force" to the Physical Society of Berlin and ever since has been regarded as one of the founders of the law of the conservation of energy: the total amount of energy in a closed system is constant.

Another happy pairing of physics and physiology in the work of Helmholtz resulted in his investigations in optics, which are of lasting importance. With the ophthalmoscope and the ophthalmometer—both of his own invention—he made fundamental contributions to the understanding of the structure and function of the human eye. As part of this study he revived and expanded the theory of color vision that had been set forth by the English physicist and physician Thomas Young early in the nineteenth century. This theory, widely held, is that color perception depends upon the presence in the retina of three kinds of nerve fibers responding to red, green, and violet light, respectively. Helmholtz applied the theory to the explanation of color blindness. His classic *Physiological Optics* was published between 1856 and 1866.

Of equal distinction were Helmholtz' studies in physiological acoustics. In this field he published papers on the quality of tones and on the mechanism of the bones of the middle ear. The first edition of his masterful work *Sensations of Tone* was published in 1863.

Helmholtz was the first to find that an acid—now known to be lactic acid—is formed in the muscle, and he was the first to measure the speed of a nerve impulse. In his later years Helmholtz did theoretical work in dynamics and electricity. One of his students was Heinrich Rudolph Hertz, who established beyond doubt the electromagnetic nature of light.

Helmholtz was a foreign member of the Royal Society of London and winner of its Copley Medal in 1873. He was also a foreign associate of the French Academy of Sciences.

HENCH, PHILIP SHOWALTER (1896–1965)

For his successful use of cortisone in the treatment of rheumatoid arthritis, U.S. physician Philip Showalter Hench was awarded a share of the 1950 Nobel Prize in medicine or physiology. The others honored with him were his colleague E. C. Kendall and the Swiss chemist Tadeusz Reichstein. (*See* Edward Calvin Kendall; Tadeusz Reichstein.)

After achieving good results in his clinical testing of cortisone, Hench continued to work on aspects of cortisone therapy that included preparation, suppression of side effects, and biochemical interaction. At about the same time that he first administered cortisone, he obtained comparable results with ACTH (adrenocorticotropic hormone), which comes from the anterior lobe of the pituitary gland. ACTH stimulates the growth of the adrenal cortex and the release of its hormones, one of which is cortisone.

Hench was born in Pittsburgh, Pennsylvania. He received his bachelor's degree in 1916 from Lafayette College, Easton, Pennsylvania. After serving briefly with the Army Medical Corps in World War I, he returned to Pittsburgh to earn his medical degree at its university in 1920. He interned at Saint Francis Hospital, Pittsburgh, and then became a fellow of the Mayo Foundation of the University of Minnesota Medical School. In 1926 he was appointed to head the Department of Rheumatic Diseases, and in 1947 he became professor of medicine.

In the study of rheumatoid arthritis during the 1930s and 1940s Hench found that the condition improved greatly in pregnant patients and in those who contracted yellow jaundice. Experiments showed that neither the jaundiced liver nor a female sex hormone was responsible for reversal in the disease. By 1938 Hench concluded that the ailment involved metabolism and that the substance he was looking for might be a hormone present in both male and female. He and Kendall, a biochemist at Mayo Clinic, began their search for the substance. Kendall isolated and synthesized substances from the adrenal cortex; and Hench, thinking that the adrenals were involved in the rhe[illegible] arthritis syndrome, experimented [illegible] vain with some of Kendall's adreno[illegible] products. He wanted to try Kend[illegible] Compound E in 1941; but becaus[illegible] an insufficient amount available f[illegible] cal testing, it was not until 1948 [illegible] first administered Compound [illegible] ned cortisone, to his patients at [illegible] Clinic, greatly reducing their pai[illegible] disability. In 1949 Hench and Ke[illegible] nnounced this first successful reme[illegible] for rheumatoid arthritis.

HENRY, JOSEPH (179[illegible] 878)

One of the unsu[illegible] es of telecommunications was [illegible] U.S. physicist Joseph Henry. Altho[illegible] he actually invented the telegraph [illegible] never patented the device, and so it[illegible] ention is commonly credited to S[illegible] Morse. Henry also discovered the [illegible] iple of induction; but Michael [illegible] ay, who published the results o[illegible] own induction experiments first, is [illegible] ed as the discoverer. Neverthele[illegible] nry did other important work in t[illegible] ld of electromagnetism, for whic[illegible] received full credit; and eventual[illegible] was chosen to be represented in th[illegible] of Fame for Great Americans.

Henry was born at A[illegible] ny, New York. Since his family was poor and he had little interest in attending school, he was apprenticed to a watchmaker at the age of thirteen. Three years later he suddenly took a new interest in education and entered Albany Academy. To pay for his education, he taught at local schools and also did private tutoring.

He had originally intended to take up the study of medicine, but in 1825 he unexpectedly was offered a road-surveying job and because of this became interested in engineering. In 1826 he began teaching mathematics and natural philosophy at Albany Academy. By 1832 he had made a name for himself with his work on electromagnetism and consequently was appointed professor of natural history at the College of New Jersey (now Princeton University).

Interested in the newly developed electromagnet, Henry in 1829 decided he could improve on the device by winding more coils of wire around the iron core and thereby increase the power.

When the wires touched, however, they short-circuited. He... was the first to overcome this problem by insulating the wires. For the insu... ng material he tore up and used his ...fe's silk undergarments. By 1831 ... had developed an electromagnet s... erful that it could lift a ton of iro...

Henry's conti... ork with, and refinement of, ele... nets led to his invention of the ... witch in 1835. The relay switch e... electric current to travel for long ...s and was an important step in ... evelopment of the telegraph. It w... nry's electromagnet that opened an ... d the key used for transmitting ... ges by telegraph. When Morse ... orking on the practical applicati... he telegraph, Henry lent him inval... technical aid.

Independent... f Faraday, Henry discovered the p... iple of induction in 1830. Althoug... enry did not receive credit for the d... overy of induction, he was acknowle... as the discoverer of self-induction, ... ability of the electric current in a c... o induce another current in itself. I... honor the unit of induction was ... d the henry.

One of Her... most important inventions was th... lectromagnetic motor, forerunner of ... lectric motors used in modern appl... s. He also invented low- and hig... istance galvanometers. In 1842 he di... ered the oscillatory nature of electr... arges. He studied solar radiation and ... spots and, using a thermogalvanom... found that sunspots radiate less he... than the rest of the solar surface.

In addition to being a brilliant physicist, Henry also proved to be a competent scientific administrator. The Smithsonian Institution in Washington, D.C., was founded in 1846, and in that year Henry became the institution's first director and secretary. He encouraged government support for scientific endeavors, made the institution a center for scientific information, and aided the growth of new sciences in the United States.

While at the Smithsonian, Henry made use of the telegraph to transmit weather reports and set up a system of weather forecasting. Henry's efforts in this area formed the basis of what became the U.S. Weather Bureau. As a member of the Federal Lighthouse Board, Henry conducted studies on sound and developed a system of fog-warning signals. During the American Civil War he directed the mobilization of scientific effort for the Union forces.

Henry was one of the original members of the National Academy of Sciences, serving as its first president from 1868 to 1878. He also helped establish the American Association for the Advancement of Science.

HERO (first century A.D.?)

All that is known of the Greek scientist and mathematician Hero, or Heron of Alexandria, has been learned from those of his written works that still exist today. Hero authored a number of outstanding works on the subjects of mathematics, physics, and mechanics. The dates of his birth and death are unknown, but it is believed that he lived in Alexandria during the first century A.D.

Hero's existing works on mechanics are *Automatopoietice*, *Belopoeica*, *Cheiroballistra*, *Mechanics*, and *Pneumatica*. They contain descriptions of such inventions as the siphon, the fountain, a primitive coin-operated machine, a force pump for a fire engine, an organ run by waterpower, and a type of simple steam engine. The steam engine consisted of a hollow sphere and two bent tubes. When water was boiled in the sphere, the steam escaped through the tubes, causing the sphere to rotate. In his works on mechanics Hero also wrote about pulleys, wheels, screws, wedges, and the inclined plane. He extended and generalized Archimedes' law of the lever.

His mathematical writings centered around geometry and are contained in *Definitiones*, *Geometria*, *Geodaesia*, *Stereometrica*, *Mensurae*, *Liber Geëponicus*, and *Metrica*. The latter was discovered at Constantinople in 1896 and is considered to be the most important of Hero's works. It takes up the subject of the mensuration of triangles, quadrilaterals, regular polygons, circles, ellipses, right cones, and spheres. It also contains a method for approximating the square root of a nonsquare number. He also worked out a method known as Hero's formula for calculating the area of a triangle, given its three sides.

Related to the geometrical writings is *On the Dioptra*, a book about land surveying. In this book he describes an instrument having the same purpose as a modern theodolite and explains how it can be applied to engineering problems, such as boring a tunnel through a mountain from both ends. He also describes a hodometer, used for showing the distance traveled by a vehicle.

In the area of physics Hero made some far-reaching observations, particularly on air. By showing that water cannot enter a receptacle that is filled with air, he demonstrated that air is a substance. Also, since air is compressible, he concluded that air consists of tiny particles.

Hero considered problems of optics and demonstrated that the angle of incidence is equal to the angle of reflection. His *Catoptrics* was written on the subject of light reflected from mirrors.

HERSCHEL FAMILY

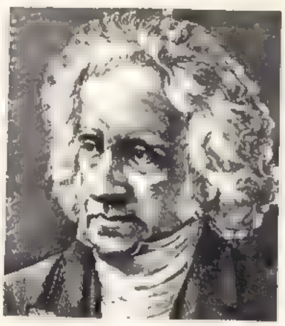
Some of the most distinguished English scientists in the history of astronomy were members of the Herschel family. Sir William Herschel (1738–1822), with the aid of his sister Caroline Lucretia Herschel (1750–1848), created the best telescopes of his time, discovered the intrinsic motion of the sun, and greatly contributed to knowledge about the Milky Way, double stars, and the constitution of nebulas. The work of Sir William was carried on by his son Sir John Frederick William Herschel (1792–1871), who also made extensive observations of the Southern Hemisphere.

William was born Friedrich Wilhelm Herschel in Hanover, Germany. His father was a musician in the Hanoverian Guard, and at the age of fourteen young Herschel also became a member of the guard. Army life was difficult during the Seven Years' War, and so in 1757 the family managed to send Herschel to England, where he changed his name to William and earned his living as a musician, eventually obtaining a good posi-

By 1774 William Herschel had made his own reflecting telescope and begun his systematic astronomical observations.

tion as an organist and music teacher at Bath and later at Leeds and at Halifax.

His main interest, however, was astronomy, and by 1774 he had made his own reflecting telescope, approximately six feet long, and begun a systematic study of the universe. In 1781 he saw what at first he thought was a comet but which proved to be the planet Uranus. He named the planet *Georgium Sidus*—the name was later changed—in honor of King George III. As a result he was made court astronomer in 1782 and granted a small annual pension. In 1787 he discovered two satellites of Uranus—Oberon and Titania—and two years later, with a forty-foot-long reflector, he discovered two satellites of Saturn—Enceladus and Mimas.



William Herschel

His studies of double stars and measurements of their positions relative to each other revealed that these stars revolve around each other, thus extending Newton's law of gravity beyond the solar system. He envisioned the Milky Way as being in the shape of a grinding wheel but was in error in his belief that the sun was in the middle of the Milky Way. He also measured the period of rotation of Saturn and discovered and cataloged 5,000 star clusters and nebulas. In 1800, while testing the temperatures of various colors in the sun's spectrum, he discovered infrared light. He was elected a fellow of the Royal Society in 1781 and was knighted in 1816.

His sister Caroline proved to be an invaluable assistant in his researches and was actually the first great woman astronomer. She devoted her life to grinding lenses for William's telescopes and later to aiding his son in his investigations. Caroline was born at Hanover, Germany; but in 1772 William visited Hanover and took her back to England with him. Her special interest was comets, and between 1786 and 1797 she independently discovered eight different comets. She performed extensive calculations associated with her brother's work and cataloged thousands of the nebulas and star clusters discovered by William. In 1828 she received the gold medal of the Royal Astronomical Society and in 1846 the gold medal for science from the king of Prussia. Meanwhile, in 1822, she had returned to Hanover, where she spent the remaining years of her life.

John Frederick William Herschel, the son of Sir William, was born at Slough, Buckinghamshire, near London. He was educated at St. John's College, Cambridge. After graduating in 1813, he became a fellow of the college. Through their work on differential calculus and other branches of mathematics, he and two friends successfully revitalized English mathematics, raising it to Continental standards.

For a short time John took up the study of law but soon abandoned that pursuit in favor of science. In 1816 he began to study astronomy and assisted his father, whose work he reexamined and extended. He also found that the Magellanic clouds are dense clusters of stars.

In 1833 he decided to examine the skies of the Southern Hemisphere and the following year went to the Cape of Good Hope in Africa, where he spent four years making charts and catalogs of nebulas, double stars, and star clusters as they appear in the Southern Hemisphere. The results of this work were published in *Cape Observations* (1847). He also published his father's and his own complete catalogs of nebulas and double stars in one volume. This work contained the observations of some other astronomers as well.

John also made important contributions to other fields of science. In 1819 he discovered the value of sodium hyposulfite as a solvent for silver salts, which led to its use as a fixing agent in photography. He was the first person to use the words *positive* and *negative* in reference to photographic images and the first person to attempt the use of photography in astronomy. Independently of William Henry Fox Talbot, he also invented the process of photography on sensitized paper.

During his lifetime he received many honors. In 1821 he was awarded the Copley Medal of the Royal Society, in 1825 the Lalande Medal of the Institut de France, and in 1826 the Gold Medal of the Royal Astronomical Society, of which he was president in 1848. He was knighted in 1831 and later was made a baronet by Queen Victoria. In 1850 he became master of the mint. On his death he was buried in W[illegible]tminster Abbey.

John had two so[illegible] who also became astronomers, Ale[illegible] Stewart Herschel (1836–1907[illegible] John Herschel (1837–1921).

HERSHEY, ALFRED [illegible] (1908–)

The biologist [illegible]acher Alfred D. Hershey was the [illegible]tive-born American on the team [illegible]ree cooperating U.S. researchers [illegible] on the 1969 Nobel Prize in medi[illegible] physiology. The two others were [illegible]lbrück and Salvador E. Luria. ([illegible] Delbrück; Salvador Edward [illegible]

Hershey, study[illegible]v viruses infect bacteria cells, bui[illegible]indings his two colleagues had m[illegible]le demonstrated that a virus infect[illegible]teria cell by injecting its own nu[illegible]nto it and leaving its protein sl[illegible]tside. He also demonstrated that[illegible]ibonucleic acid (DNA), which ma[illegible] the virus's nucleus, was responsi[illegible] genetic mutations in succeedin[illegible] generations.

The combined r[illegible]h of the three scientists, working[illegible]tely but cooperatively after 194[illegible] known as the Phage Group, wa[illegible]lied in many ways. Without it[illegible]nes against a number of viral di[illegible] such as polio and mumps, could [illegible]ve been developed. The Nobel [illegible]ommittee said that "indirectly, [illegible]scoveries also bring about an incr[illegible] understanding of the mechanism o[illegible]ritance and of those mechanisms th[illegible]ntrol the development, growth, an[illegible]tion of tissues and organs."

Hershey was born[illegible]wosso, Michigan, reared in Lansin[illegible]nd educated at Michigan State Univ[illegible]y, East Lansing. After receiving his doctorate he taught for many years at Washington University Medical School, Saint Louis, Missouri. In 1950 he joined the Department of Genetics of the Carnegie Institution of

Alfred Hershey

Washington at Cold [illegible]pring Harbor, New York. Twelve yea[illegible]ater he was named its director. In [illegible] he was elected a member of the N[illegible]nal Academy of Arts and Sciences.

HERTZ, GUSTAV [illegible]7–)

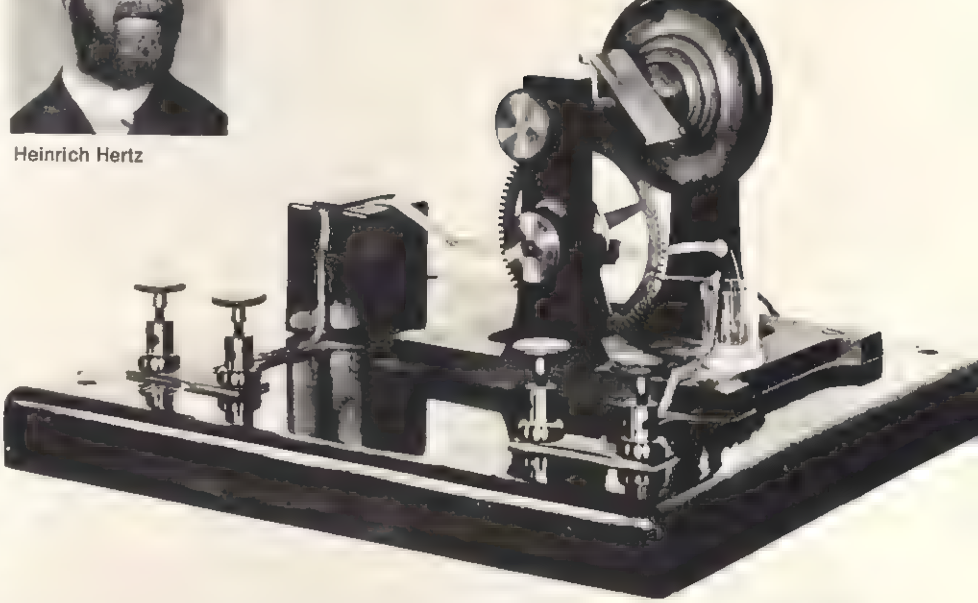
The work [illegible] German physicist Gustav Hertz [illegible] laws governing the impact of an el[illegible] with an atom won him, along wit[illegible]s Franck, the 1925 Nobel Prize i[illegible]. The experimental results of the[illegible]k agreed with the modern theor[illegible]the structure of the atom. (*See* Ja[illegible]ranck.)

From their [illegible] on electron-atom collisions Hertz [illegible]ranck found that for ionization of [illegible]m the electron must have a certai[illegible]imum energy, or ionization poten[illegible] Hertz measured the ionization po[illegible]al of various gases, such as argon [illegible] neon, and studied the excitation of [illegible]tral radiation by electron impacts [illegible]the exchange of energy when slow [illegible]ons collide with gas molecules. H[illegible] developed a method for separatin[illegible] isotopes by diffusion.

Hertz, th[illegible]w of another famous German p[illegible] Heinrich Rudolph Hertz, was [illegible]t Hamburg, Germany, and educat[illegible]ne universities of Göttingen, Mu[illegible]d Berlin. Two years after recei[illegible]is doctorate from the University o[illegible]rlin in 1911, he began teaching ph[illegible]here. From 1920 to 1925 he worked i[illegible]physics laboratory of the Philips inca[illegible]scent lamp factories in the Nether[illegible] In 1925 he returned to Germany to [illegible]me professor of physics at the Univ[illegible]y of Halle. Then in 1928 he was appointed professor of physics and director of the Physical Institute of the Technische Hochschule at Berlin-Charlottenburg.

Being of Jewish descent, Hertz was forced to give up his position at Berlin-Charlottenburg after the Nazis came to power. He resigned in 1934 but remained in Germany and became director of a research laboratory belonging to the Siemans Company. Hertz survived World War II and was in Berlin when the Russians entered the city. After 1945 he worked on research projects in the Soviet Union and in East Germany.

Heinrich Hertz



Among the many experiments that Heinrich Hertz performed relating to electromagnetic radiation was one involving the determination of the light spectrum of an electric discharge.

HERTZ, HEINRICH RUDOLPH (1857–1894)

Before his untimely death at the age of thirty-six, the German physicist Heinrich Rudolph Hertz had demonstrated the existence of electromagnetic waves and had shown that these waves are essentially the same as light waves. His discoveries led directly to the development of wireless telegraphy and later to the development of radio broadcasting.

Hertz was born in Hamburg, Germany. At first he studied engineering but then turned to physics. In 1878 he went to Berlin, where he studied with the famous German physicist Hermann von Helmholtz. After two years as privatdocent, or unpaid lecturer, at Kiel, he was appointed professor of physics at a polytechnical school in Karlsruhe in 1885. From 1889 until his death he was professor of physics at the University of Bonn.

The bulk of his work on electromagnetic waves was done while he was at Karlsruhe. Earlier, Helmholtz had suggested that Hertz work on establishing experimentally the relation between electromagnetic actions and the polarization of a dielectric because the Berlin Academy of Sciences was offering a prize for the successful completion of such a project. Although Hertz was not particularly enthusiastic about it, he began working on the problem and in 1888, while experimenting in this area, found that he could generate electromagnetic radiation. He measured the length and velocity of these electromagnetic waves, which came to be called hertzian waves and radio waves, and showed that they can be reflected, refracted, and polarized in the same manner as light. These experiments and studies proved James Maxwell's theory about the electromagnetic nature of light. (*See* James Clerk Maxwell.)

In the course of this work Hertz became the first scientist to observe the photoelectric effect. He noticed that ultraviolet light affects the ease with which a spark can be sent across the gap between two metal balls by an oscillating electric circuit. Many years later the photoelectric effect was explained by Albert Einstein.

At Bonn, Hertz experimented with the discharge of electricity into rarefied gases and did work on cathode rays. Apparently he narrowly missed discovering x-rays. His last major work was a treatise called *Principles of Mechanics.*

HESS, VICTOR FRANCIS (1883–1964)

For his discovery of cosmic radiation the Austrian physicist Victor Francis Hess received the 1936 Nobel Prize in physics. He shared the prize with Carl David Anderson, who discovered the positron. (*See* Carl David Anderson.)

As early as 1911 Hess studied electric conduction in the atmosphere. Scientists were puzzled by the presence of background radiation in the atmosphere and thought it might emanate from the Earth's surface. Hess sent up balloons (as high as six miles) with devices to measure the radiation and found that ionization increased with altitude. During a solar eclipse the radiation remained high, eliminating the possibility that it came from the sun. Thus, Hess proved that the radiation came from outer space, and in 1925 Robert Andrews Millikan coined the term *cosmic rays* to describe this type of radiation.

Cosmic rays involve highly concentrated energy. By working with cosmic rays, scientists have the opportunity to encounter particles not encountered else-

where. Not only did Anderson discover the positron as a result of Hess's work, but Cecil Frank Powell also discovered the pi-meson.

Victor Hess

Hess was born in Schloss Waldstein, Austria. He received his doctorate from the University of Graz in Austria in 1906. From 1910 to 1920 he was an assistant at the Institute for Radium Research of the Vienna Academy of Sciences. During this period he also lectured on physics at the Vienna Veterinary College. In 1920 he was appointed associate professor at Graz. He took a leave of absence in 1921 to become director of the research laboratory of the U.S. Radium Corporation in Orange, New Jersey. In 1923 he returned to Graz and was made a professor two years later. He was appointed head of the new Institute for Radiation Research in Innsbruck in 1931. In 1938 Hess emigrated to the United States and became a professor of physics at Fordham University, New York City. He became a naturalized U.S. citizen in 1944.

HESS, WALTER RUDOLF (1881–)

Researches by Walter Rudolf Hess, Swiss physiologist, into the functional organization of the interbrain were rewarded in 1949 when he shared the Nobel Prize in physiology or medicine with the Portuguese neurosurgeon Egas Moniz. With his own specialized technique, Hess discovered that the interbrain controls the autonomic nervous system. (*See* Antonio Caetano de Abreu Freire Egas Moniz.)

Walter Hess

Besides his painstaking examination and mapping of the diencephalon, or interbrain, Hess did research on blood and blood pressure and the physiology of respiration in his efforts to understand the physiological bases for the body's organization. From 1925 on, he published extensively.

Hess, the son of a physics teacher, was born in Frauenfeld, Switzerland. He received his medical degree in 1906 from the University of Zürich. After six years as an ophthalmologist, he became an assistant in physiology, first in Zürich and later in Bonn, Germany. In 1917 he was named director of the Department of Physiology at the University of Zürich and returned to Switzerland.

He studied cerebral localization by applying fine probe electrodes that allowed for strictly local stimulation or destruction of brain tissue in the laboratory animals. Because it was impossible for him to determine exactly where the end of the probe was during an experiment, Hess analyzed the brain tissue in serial section afterward in order to locate the centers that control various body functions. This systematic mapping laid the groundwork for successful surgery in certain motor disturbances.

Besides many monographs written in German, his works also include translations, such as *The Functional Organization of the Diencephalon, Hypothalamus and Thalamus*, and *The Biology of Mind*.

HEVESY, GEORGE DE (1885–1966)

The first scientist to use radioactive isotopes as tracers for the study of processes within living organisms was the Hungarian-Swedish chemist George de Hevesy. For his work in this area he received the 1943 Nobel Prize in chemistry. He also was the co-discoverer of the element hafnium.

Hevesy was born at Budapest, Hungary, and educated at the University of Budapest, the Technische Hochschule in Berlin, Germany, and the University of Freiburg, Germany, from which he received his doctorate in 1908. After working two years as an assistant at the Technical High School in Zürich, Switzerland, he received an honorary fellowship at the University of Manchester, England, where he studied with Sir Ernest Rutherford.

While at Manchester he worked unsuccessfully on the separation of radium D from lead chloride. Later, during a brief stay in Vienna, he found that by adding radium D to lead he could trace the chemical processes of lead by means of its radioactivity.

He returned to Bud[illegible]pest in 1913 and continued his work o[illegible] lead tracers. In 1918 he became a p[illegible]sor at the University of Budapest [illegible] in 1920 to accept a post at the In[illegible] of Physics at the University of Co[illegible]gen, Denmark.

In 1923, at Copen[illegible]n, he made his two greatest discove[illegible] Working with Dirk Coster and und[illegible] the direction of Niels Bohr, he disc[illegible] the element corresponding to ato[illegible] number 72 on the periodic table. [illegible] called it hafnium, the Latin na[illegible] Copenhagen.

His other discove[illegible] at radioactive isotopes could be us[illegible] tracers in living organisms, had f[illegible]hing implications and resulted [illegible]nded knowledge of metabolic [illegible]es. After he first began experim[illegible] with radioactive tracers for stu[illegible] chemical reactions, he used label[illegible] lead to determine the solubility of [illegible]tain salts. In 1923 he watered plant[illegible]th water containing a radioactive i[illegible]e of lead and found that he was ab[illegible] trace the absorption of water in [illegible] plants. Lead, however, being pois[illegible] to living organisms, was not a [illegible]le indicator. After the discovery of [illegible]cial radiation it became possible to [illegible]otopes of elements not foreign to l[illegible] things.

In 1934 Hevesy firs[illegible]ployed stable isotopes in biologica[illegible]ies. He used heavy water to study [illegible]in processes in goldfish and in the [illegible]n body, and radioactive phosphor[illegible] study the blood, brain, and skel[illegible]. In 1935 he invented the techni[illegible] of activation analysis. He also did w[illegible] on the separation of isotopes of chlorine, mercury, and potassium.

He became professor of physical chemistry at the University of Freiburg in 1926, but in 1934 he returned to Copenhagen. After Nazi troops invaded Denmark, Hevesy fled to neutral Sweden in 1943, where he was appointed a professor at the University of Stockholm. Eventually he became a Swedish citizen.

In 1939 Hevesy was elected a fellow of the Royal Society and was later awarded its Copley Medal. He received the U.S. Atoms for Peace Award in 1959. In addition to his numerous other awards and medals, he received honorary degrees from many universities.

HEYMANS, CORNEILLE JEAN FRANÇOIS (1892–1968)

The Belgian physiologist Corneille Heymans concentrated his research on the physiology of the circulatory and respiratory systems. He was awarded the 1938 Nobel Prize in physiology or medi-

cine for discoverin… he importance of the sinus and aort… nechanisms in the regulation of breath…

He began his w… n this area in 1924 in collaboration w… father, who was also a physiologis… ymans found that different pressu… uli and changes in the oxygen t… f the blood produce responses … carotid sinus, the carotid body, … aortic bodies, which regulate b… ressure and respiration. Connect… h this work was Heyman's devel… t of the physiological technique … ss circulation, by which blood is … d from the carotid artery and jug… in of one animal into the organ … other animal.

Heymans wa… in Ghent, Belgium, and graduated … dicine from the university there i…). He then pursued postgraduate w… at the Collège de France, the u… sities of Lausanne (Switzerland) … Vienna (Austria), and at Wester… erve University Medical School, C… land, Ohio.

In 1923 he b… e a lecturer in pharmacology at th… iversity of Ghent and in 1930 was ap… ted professor of pharmacology, suc… ing his father, J. F. Heymans. He … red at universities all over the world, … luding New York University, Har… University Medical School, and W… tern Reserve University Medical Scho… He received honorary degrees fro… ral universities and many award… ding prizes from Belgium's Royal … demy of Medicine (of which he was … member) and the Institut de France

HEYROVSKY, JAROSLAV (1890–1967)

The inventor of the polarograph, Czechoslovakian chemist Jaroslav Heyrovsky, was also the founder of the analytical science of polarography. For developing the polarographic analytical technique, he was awarded the 1959 Nobel Prize in chemistry.

The events that led to the development of polarography began in 1918 when Heyrovsky undertook the study of the electrocapillarity of mercury. Since it was tedious work to drop mercury through a solution to which external potential had been applied and then weigh the drops of mercury, Heyrovsky developed an electrochemical method for performing the task. He set an electric current flowing through the solution and then dropped mercury from a glass capillary, through the solution, and down to a pool of mercury. In this way he was able to take the necessary measurements.

He also found, however, that the electric current increased in steps as the voltage was increased and that this was

Jaroslav Heyrovsky

in turn proportional to the concentration of ions in the solution, each type of ion requiring a different amount of voltage. Heyrovsky recognized the importance of this method as an analytical technique.

The current-voltage curve plotted for analyzing an electrolyte by this method came to be called a polarogram. In 1924 Heyrovsky developed the polarograph, a device for automatically recording polarograms. Polarography eventually became an important technique in qualitative and quantitative analysis, in many areas of physical chemistry, and in the detection of cancer. In the 1940s Heyrovsky developed alternating current oscillographic polarography for detecting substances not found by using ordinary polarography.

Heyrovsky was born in Prague, Czechoslovakia, which was then a part of Austria-Hungary. He studied at the Charles University of Prague and University College, London, and in 1918 received his doctorate from the former.

During World War I he worked in a military hospital. Then in 1920 he joined the faculty of the University of Prague, becoming an associate professor of physical chemistry in 1922 and a full professor in 1926. From 1950 to 1963 he was director of the newly formed Institute of Polarography of the Czechoslovak Academy of Science. He was elected a foreign member of the Royal Society in 1965.

HIDEKI. See Yukawa, Hideki.

HILL, ARCHIBALD VIVIAN (1886–)

The work of the English physiologist Archibald Vivian Hill centered mainly around the physiology of muscles. For his research on the heat produced by muscles he shared the 1922 Nobel Prize in physiology or medicine with Otto Meyerhof. (*See* Otto Fritz Meyerhof.)

By ingeniously adapting thermocouples to his needs, Hill was able to take exact measurements of the heat produced by muscle contractions. He found that heat is produced after the contraction and that no oxygen is consumed until after the contraction, when it is consumed in excess. His work showed the relation between muscle condition and the amount of heat produced and led to a greater understanding of muscle action and muscular fatigue. He also studied the amount of heat produced by nerves following their stimulation.

Hill was born at Bristol, England. He attended Trinity College, Cambridge, where he studied mathematics, later turning to physiology. From 1910 to 1916 he was a fellow of Trinity College,

Archibald Hill

and during that time he began his independent research on the physiology of muscles.

In 1920 he was appointed professor of physiology at the University of Manchester, and from 1923 to 1925 he was professor of physiology at University College, London. He served as Foulerton Research Professor of the Royal Society, to which he had been elected in 1918, from 1926 to 1951 and as its secretary from 1935 to 1945. During World War II he represented Cambridge University in Parliament as an Independent Conservative and was a member of various groups concerned with defense and scientific research. In 1948 he was awarded the Copley Medal.

HINSHELWOOD, SIR CYRIL NORMAN (1897–1967)

The work of the English physical chemist Sir Cyril Norman Hinshelwood on reaction kinetics was of fundamental importance to an understanding of the complexities of the individual steps involved in chemical reactions. For his research in this area, Hinshelwood shared the 1956 Nobel Prize in chemistry with Nikolai N. Semenov. (*See* Nikolai Nikolaevich Semenov.)

Hinshelwood explained the mechanism by which hydrogen combines with oxygen to form water. By studying the kinetics of the process, or rate at which the reaction takes place, he was able to

deduce the complex steps involved in what appeared to be a simple reaction. He found that a complicated chain of events occurs: the hydrogen molecule divides into atomic hydrogen; a hydrogen atom combines with one oxygen molecule, forming a hydroxyl atom and freeing one oxygen atom; and the free oxygen atom then combines with a hydrogen molecule, freeing a hydrogen atom. This chain reaction continues until all the hydrogen and oxygen have combined to form water.

Sir Cyril Hinshelwood

He also found an explanation for explosive reactions involving hydrogen and oxygen. He discovered that temperature and pressure affect the rate at which molecules combine and that under certain conditions a branching chain reaction results in an explosion. Since the combining of hydrogen and oxygen is a fundamental chemical reaction, the understanding of this process is important to an understanding of the mechanisms of other chemical reactions.

After completing this research, Hinshelwood began studying the chemical changes in bacterial cells by using the techniques he had developed in inorganic chemistry for his investigation of bacteria. In physiochemical terms he explained how bacteria respond biologically to changes in their environment. He claimed that when exposed for long periods of time to an antibiotic, bacteria will develop a more or less permanent resistance to the drug.

Hinshelwood was born in London, England, and educated at Balliol College, Oxford. He graduated in 1920 and became a fellow of the college; then, from 1921 to 1937, he was a fellow of Trinity College, Oxford. In 1937 he was appointed Doctor Lees Professor of Chemistry at Oxford University, where he remained until 1964, when he became a senior research fellow at Imperial College, London.

During his lifetime he received many awards and honorary degrees from organizations and universities throughout the world. He was elected a fellow of the Royal Society in 1929, received its Davy Medal in 1943 and its Royal Medal in 1947, and served as president from 1955 to 1960. In 1946–1948 he was president of the Chemical Society, and in the latter year he was knighted.

HIPPARCHUS (second century B.C.)

The Greek scientist Hipparchus was the first astronomer to inaugurate a series of systematic observations, which still retain their usefulness today. Although he supported an erroneous system of the universe, later known as the Ptolemaic, he was led into it by a rational interpretation of his observations, which were unrivaled in their completeness at that time. Their depth and scope make Hipparchus the founder of modern astronomical observation and the originator of trigonometry.

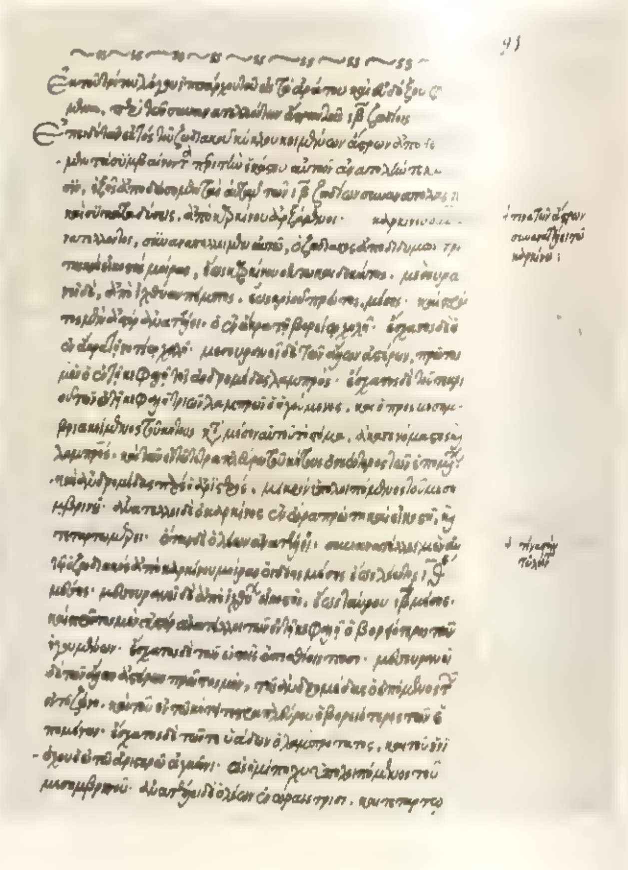
Hipparchus was born in Nicaea, one of the chief cities of Bithynia, and lived for some time in Alexandria and on Rhodes, where he did most of his work. He founded an observatory there, in which he is definitely known to have worked in the years 128 and 127 B.C. What little information there is about his life is drawn from the references of admirers and from astronomical observations dating from the years 161 to 127; the first of these, which were carried out in Alexandria, may not be the work of Hipparchus, but those dating from 146 to 127 can certainly be attributed to him.

Although most of [illegible] writings have disappeared, much of [illegible] content can be drawn from such [illegible] as Strabo and Ptolemy. The latter [illegible] ived three centuries later, often re[illegible] Hipparchus in his *Almagest*, rep[illegible] is words and praising his love o[illegible] nd his search for truth. Yet it was [illegible] yclopedic nature of the *Almages*[illegible] that indirectly caused the loss of [illegible] ks of Hipparchus. In ancient ti[illegible] hen a skillful compendium was n[illegible] a great work or a whole field of kn[illegible] ge, it was then copied and the orig[illegible] as frequently neglected or even lost [illegible] hough it is difficult to establish how [illegible] h of the *Almagest* is Hipparchus' w[illegible] and how far it is attributable to Pto[illegible], it is certain that Ptolemy used his [illegible] decessor's basic ideas and materials, c[illegible] pleting and perfecting some of them [illegible] process.

According to the [illegible] lian concepts held at the time of [illegible] archus, everything connected w[illegible] heavens was eternal, incorruptibl[illegible] d immutable. Such phenomena as [illegible] appearance of meteorites and come[illegible] attributed to the atmosphere, corr[illegible] n the first case

Few of Hipparchus' works are still extant, most of them having been lost t[illegible] the ages.

Hipparchus



but erroneously in the second. In 134 B.C., Hipparchus obser[illegible]d a nova, or temporary star, in the c[illegible]stellation Scorpio, a revolutionary disc[illegible]ry. Hipparchus' conclusion that cele[illegible] bodies are subject to change was o[illegible]ital importance, for it involved ado[illegible] a completely new principle and c[illegible]ng a stellar catalog, or a map of th[illegible] Until then celestial charts had be[illegible]sidered superfluous because the sk[illegible] its set stars was always there for [illegible]ody to see. Hipparchus, however, [illegible]rently thought that there might [illegible]ppreciable changes, though probab[illegible]w and gradual. His catalog, which [illegible]noted in many astronomical works [illegible]es it possible to establish what chan[illegible]ve occurred since his time. It reveal[illegible] example, that the star that is now t[illegible]cond brightest in the constellation o[illegible]on, Betelgeuse, at that time outshon[illegible]el, which today is the dominant sta[illegible]

Ancient astr[illegible]mers did not study the distance of st[illegible] because they believed that the stars [illegible]e attached to a revolving sphere. T[illegible]serve their exact positions on the [illegible]stial vault, Hipparchus constructed a[illegible]strument similar to a theodolite, w[illegible] instead of a sight, had two holes in [illegible]nment with the direction of the in[illegible]ent's axis. This enabled him to obser[illegible]e positions of the stars accurately a[illegible]o discover that, compared with s[illegible]r observations made by Timocharis [illegible]years before and by even earlier Bab[illegible]nians, their longitudinal position had [illegible]nged. From this, Hipparchus conclud[illegible] that the ecliptic plane—the interse[illegible] of the Earth's orbit with the celestial sphere—must have moved in a direction contrary to the diurnal rotation: he had found the phenomenon of the precession of the equinoxes. This discovery led him to establish more accurately both the tropical and the sidereal years and allowed him to forecast the eclipses of the sun and the moon more accurately than had been possible earlier. Resuming the studies and tentative calculations made by Aristarchus of Samos, he tried to determine the distances and volumes of the sun and the moon. Although his figures were off, they were more accurate than any given previously and were generally accepted until the eighteenth century.

Hipparchus was also an able mathematician, being the inaugurator of a new branch of mathematics, trigonometry, which proved so useful in astronomical calculations that it became a complementary science to astronomy. At the time of Hipparchus, of course, there was no method for working out the trigonometric functions of an angle without going into lengthy calculations; but this was, in fact, how Hipparchus prepared his equivalents of the modern trigonometric tables of sines, cosines, and tangents. According to Theon of Alexandria, Hipparchus wrote a twelve-volume treatise on the chords of a circle that apparently contained the general theory of trigonometry as well as a number of tables. These gave the value of the chords that subtended various arcs, degree by degree, on the basis of the division of the circle into 360°, a division that was first conceived and adopted by Hipparchus in this treatise.

Following the encyclopedic tendencies of his time, Hipparchus also turned his attention to geography and cartography. He invented stereographic projection and tried to establish a basic geodetic grid, or a graphic representation of the terrestrial globe, systematically using latitudes and longitudes to localize different points on the Earth's surface.

HIPPOCRATES (460?–?377 B.C.)

Hippocrates

Although Hippocrates is shown in the company of Plato and another Greek physician, Pedanius Dioscorides, he was actually a contemporary of only Plato. Dioscorides lived much later—in the first century A.D.

The history of medicine begins with the history of man, since it is connected with the instinct of self-preservation, common to all living creatures, and with two fundamental problems of humanity: sickness and death. It is understandable that in every civilization the first empirical notions of medicine were closely linked with religion or, more exactly, with supernatural traditions. In every primitive society, whether contemporary or prehistoric, faith and religious rites are mingled with superstition and magic, and the functions of priest and doctor are inseparable.

Among the Greeks, heirs to many different cultures, various forms of popular medicine, as the Homeric epics show, were widely practiced before a real medical science developed. Miraculous powers were attributed to all the divinities, but the god of medicine was Asclepius, who was perhaps a deified hero. Many temples were dedicated to him, and he was venerated with particular fervor at Epidaurus. The inscriptions and votive offerings that patients who had recovered left there give evidence of a special therapeutic process, known as incubation or temple sleep, during which the patient, after a special diet and suitable medicines, was left for twenty-four hours in a place conducive to hypnotic visions, which were interpreted by the priests.

By the fifth century B.C. there were two rival schools of medicine in Greece: that of Cnidus, where the teaching, influenced by the naturalist philosophers, such as Anaximander and Thales, was based on perceptible phenomena, and that of Cos, where, under the aegis of Pythagoras, studies had a bias toward mathematics and astronomy. The presence of these schools proves the existence of scientific investigation and lay medicine, the methods, theories, and, above all, spirit of which were already far removed from any form of irrational mysticism.

It was during this time on the island of Cos that Hippocrates was born to Heraclides and Phenarete. His earliest biographer, Soranus, who lived several centuries after him, affirmed that Hippocrates was of divine descent, assigning him to the twentieth generation of Asclepius. Undoubtedly the descendant of a family of well-known and esteemed doctors, Hippocrates is said to have studied first with his father, then with Herodicus of the school of Cnidus and with the athlete Herodicus of Salimbria, and fi-

nally with the philosophers Gorgias and Democritus. To complete his education he seems to have visited Thasos, Thessaly, Propontis, Athens, Scythia, Egypt, and Libya. In Egypt he is thought to have acquired useful knowledge of dietetics, hieroglyphics, cosmography, and the art of interpreting dreams from the priests. The last of these studies interested him so passionately that he can be considered a precursor of Sigmund Freud.

The influence of the nearby East, particularly of Babylonian and Egyptian medicine, is felt in the Hippocratic notion that individual nature, considered as vital energy, regulates the energy necessary for life.

The most significant part of Hippocrates' activity was in his native country, where he brought such great fame to the medical school that he has since universally been considered the founder of modern medicine. According to legend, he freed Athens from the plague that struck the city between 430 and 425 B.C. After noticing that blacksmiths had remained exceptionally immune from contagion, Hippocrates purified the town with great fires. Always ready to give treatment and understanding to whoever was in need, Hippocrates had both the illustrious and the unknown as patients. One famous case was that of Perdiccas, king of Macedonia, whom he cured of a serious nervous complaint after diagnosing its secret cause: the young man was irresistibly in love with his father's beautiful mistress. Another case involved Democritus, who was visited by Hippocrates at the urgent request of his fellow citizens, who were sure that the great philosopher was mad. Hippocrates, however, was greatly struck by the old man's wisdom and decided that it was the others who were mad. The great Persian king Artaxerxes also wished to have Hippocrates as his physician, but Hippocrates, scorning the high fees offered him and not wishing to desert his own people, refused to go to the traditional enemy of his people.

Faced with the grave moral problems that a doctor has to deal with in the practice of his profession, Hippocrates felt the need to summarize the fundamental principles of medical ethics in the form of an oath, the pattern of conduct that has since traditionally served as an ethical ideal or code for doctors.

Hippocrates died near Larissa, Thessaly, at an advanced age. His sons, Thessalus and Draco, and his followers continued to practice the art of medicine according to his teachings.

It was his fame and the veneration in which he was held by posterity that created a myth around Hippocrates, making it difficult to distinguish fact from fiction. Moreover, few of his contemporaries mention him (there are only two passages in Plato and one in Aristotle), and the writings that have survived under the name *Hippocratic Collection* are in reality a compilation of materials by several writers of the Hippocratic school.

Hippocrates' teaching was founded on reason and experience, on the rational conception of illnesses as natural phenomena, on the criterion of the healing power of nature, on therapy as a means of sustaining this power in the patient, and on the ethical importance of the medical profession. He was opposed both to attributing ailments to the influence of the gods and to making a priori diagnoses, and he introduced the method of direct examination of the patient. He considered every clinical case separately, as is shown by his objective and thorough description of forty-two cases in the work *Epidemics*. His professional honesty even led him to emphasize his own errors, since he considered it useful "to know about doctors' failures as well as about the factors that caused them."

In pathology he affirmed that the organism is, not an assemblage of organs, but a combination of four humors: blood, phlegm (or mucus), yellow bile, and black bile. On their equilibrium depend the individual's well-being and health and also his temperament, which may be sanguine, phlegmatic, bilious, or atrabilious. An essential condition for life is "innate heat," which is greatest in youth, diminishes with age, and ceases at death. The organism, on the other hand, adapts itself to the stimuli of the external environment: in other words, to the alternation of the seasons, of day and night, of the lunar phases, and of climatic factors. Hippocrates was therefore the first to affirm that the individual is influenced by his environment and to advance the notion of his adaptability to this environment. Any disruption of the balance between the cosmos and the human body causes a disruption of the humoral balance, with resulting illness, the elimination of which must occur through the natural reaction of the organism, which tends spontaneously to recovery and possesses the means to achieve it. Nature itself is the curer of ailments, and the doctor must follow its guidance and alleviate the patient's suffering.

The treatments that he prescribed were simple: a healthful diet, light beverages, massage and baths, an occasional purgative, and, in some cases, bleeding. Admittedly, many of his ideas were wrong because quite a number of basic principles were unknown to him. On the other hand, it should be remembered that he had to base his diagnoses exclusively on symptoms, for the most part external, and that he had never dissected a corpse.

His teachings served as a theoretical

A thirteenth-century miniature illustrating a work by Hippocrates shows medicine being administered to a patient. A kindly man, Hippocrates tended people from all walks of life.

basis for medical science for 2,000 years; and although they were sometimes misunderstood, they formed a thread that leads through the entire history of medicine. There is a li[illegible] between them and a present-day sci[illegible] trend, which is, in fact, called [illegible]ippocratism, from which psychoso[illegible] medicine derives. The enduring [illegible]ess of his thought lies in a reconc[illegible] between the laws of nature and th[illegible]ical art, in a fusing of natural ph[illegible]hy and medicine, which for Hip[illegible]es was an experimental science

HODGKIN, AL[illegible]OYD (1914–)

For accomp[illegible]nts that advanced the understand[illegible] nerve impulses in terms of physi[illegible]d chemistry, British biophysicist Al[illegible]yd Hodgkin shared the 1963 Nob[illegible] in physiology or medicine. His [illegible]borator A. F. Huxley and Sir J. C. E[illegible] an Australian physiologist, were [illegible]ners. (*See* Sir John Carew Eccles; [illegible]ley Family.)

Hodgkin and [illegible]uxley were honored for research on t[illegible] ionic mechanisms involved in excit[illegible] and inhibition in the peripheral an[illegible]ntral portions of the nerve cell me[illegible]ne. They showed that a nerve impul[illegible] wavelike conduction from point t[illegible]int—involves at each point an ioni[illegible]erchange between the sodium-rich [illegible]m outside the nerve fiber and its [illegible]ssium-rich core. The colleagues us[illegible]e comparatively large nerve fibers [illegible]ttlefish for their measurements an[illegible]servations.

Hodgkin wa[illegible]orn at Banbury, Oxfordshire, Englan[illegible] and educated at Trinity College, Cam[illegible]idge, where he became a fellow in 19[illegible]. During World War II he worked on radar for the Air Ministry and the Ministry of Aircraft Production. Afterward he was a lecturer and assistant research director in the Department of Physiology at Cambridge University from 1945 to 1952, when he became Foulerton Research Professor.

In his years of research Hodgkin discovered the first experimental proofs that electricity is the direct causal agent of impulse propagation. He and Huxley worked together on muscle activity also.

Hodgkin was elected to the Royal Society of London in 1948 and was awarded its Royal Medal ten years later. He wrote *Conduction of the Nervous Impulse* in 1963.

HODGKIN, DOROTHY MARY CROWFOOT (1910–)

The molecular structure of vitamin B_{12} remained a mystery until solved through x-ray crystallographic analysis by the British chemist Dorothy Hodgkin. Her achievement was especially noteworthy because the vitamin B_{12} molecule is one of the most complicated nonprotein molecules found in nature, and previous analyses had disclosed little of its structure except that it contains cobalt at its center.

In 1948 Dorothy Hodgkin and her colleagues obtained their first x-ray photographs of vitamin B_{12} crystals and by 1956 had determined the crystal structures of the B_{12} compounds. Their research consisted of collecting complete three-dimensional diffraction data for four crystals: air-dried vitamin B_{12}, wet vitamin B_{12}, vitamin B_{12}·SeCN, and a hexacarboxylic acid derived from vitamin B_{12}. To show the actual arrangement of known and unknown groupings of atoms within the crystals, they recombined the x-rays scattered by the electrons surrounding the atoms of the crystals. In the analysis of each of the four crystals the positions of the heavy atoms—cobalt or cobalt and selenium—were located, and then three-dimensional Fourier series were calculated based only on these heavy-atom positions. The resulting distributions gave an approximation to the correct electron density series, and a series of calculations of successive degrees of approximation to the correct electron density distribution solved the crystal structure of the hexacarboxylic acid derived from B_{12}. This, in turn, led to a solution of the chemical structure of vitamin B_{12}.

In addition to her research on vitamin B_{12}, Dorothy Hodgkin is also known for her work with pepsin, the sterols, and penicillin. While studying at Cambridge University, 1932–1934, she collaborated with J. D. Bernal on the first x-ray diffraction photograph of a protein, pepsin, and with him and I. Fankuchen in a study on sterols. From 1942 to 1946 she was engaged in the structural analysis of penicillin and later solved the chemical structure of cephalosporin C, a drug closely related to penicillin. Meanwhile, in 1945, she had completed the crystallographic analysis of cholesterol iodide.

Dorothy Crowfoot was born in Cairo, Egypt. Her father was employed in the Egyptian education service, and she early developed an interest in the Near East, even going on an archaeological expedition to Jerash in Transjordan. She was educated in England, at the Sir John Leman School, Beccles, and at Somerville College, Oxford. After the two years at Cambridge she returned to Oxford to teach and do research. In 1937 she married the writer and lecturer Thomas Hodgkin, and in the 1960s she spent some time with him at the University of Ghana in Accra, where he was director of the Institute of African Studies.

For her work in determining the structure of biochemical compounds, especially that of the vitamin B_{12} molecule, Dorothy Hodgkin received the 1964 Nobel Prize in chemistry. Many other honors came to her, too. In 1947 she became a fellow of the Royal Society, in 1957 a Royal Medallist, in 1960 the first Wolfson Research Professor of the Royal Society at the University of Oxford, and in 1965 a member of the Order of Merit.

HOFF. See Van't Hoff, Jacobus Henricus.

HOFSTADTER, ROBERT (1915–)

For his research on atomic nuclei and nucleons the U.S. physicist Robert Hofstadter shared the 1961 Nobel Prize in physics with Rudolf Mössbauer. Using a high-voltage linear electron accelerator, he explored the structure of atomic nuclei by means of electron scattering and also made quantitative measurements of the sizes and shapes of nucleons—protons and neutrons—considered to be the building blocks of nuclei. (*See* Rudolf Ludwig Mössbauer.)

By observing the scattering effects that atomic nuclei have on high-energy electrons, Hofstadter reached certain conclusions about the structure of the nucleus. He noticed that the more energetic the electrons, the closer they approach the nucleus and the more sharp the details. By 1961 he had deduced that protons and neutrons consist of a central core of positively charged matter surrounded by two meson shells. Mesons are of fundamental importance in the forces and interactions between nucleons. In the proton the mesons are both positively charged; but in the neutron, one of the shells is negative, making for an overall effect of zero. He also correctly predicted the existence of mesons more massive than those already known and called them the rho-meson and the omega-meson.

Hofstadter was born in New York City and educated at the City College of the City of New York, from which he graduated *magna cum laude* in 1935, and at Princeton University, where he obtained his doctorate in 1938. During World War II he worked on military equipment at the National Bureau of Standards and the Norden Laboratories Corporation. On his return to Princeton in 1946, he did research on infrared spectroscopy, photoconductivity, and crystal and scintillation

counters. In 1950 he went to Stanford University, Palo Alto, California, where he became professor of physics, as well as head of the department. It was at Stanford that he first used a high-voltage linear electron accelerator to explore the structure of atomic nuclei.

In addition to many scientific papers, Hofstadter also wrote *High-Energy Electron Scattering Tables* (with Robert Herman; 1960) and edited *Nuclear and Nucleon Structure* (1963) and *Nucleon Structure* (with L. I. Schiff; 1964). He was elected to the National Academy of Sciences in 1958.

HOLLEY, ROBERT WILLIAM (1922–)

In recognition for work in deciphering the genetic code, the biochemist Robert W. Holley was one of three U.S. scientists who shared the 1968 Nobel Prize in medicine or physiology. His co-winners were Har Gobind Khorana and Marshall Nirenberg. Working independently, they examined the nature of basic biochemical substances in the cell's chromosomes: proteins, amino acids, and DNA (deoxyribonucleic acid) and RNA (ribonucleic acid)—the two primary vehicles of heredity. The work of the three men combined to shed the first real light on the genetic mechanisms through which cells copy the qualities of their ancestors. (*See* Har Gobind Khorana; Marshall Warren Nirenberg.)

Robert Holley

Holley's work related principally to transfer-RNA. After years of research with yeast, he determined the chainlike structure of the RNA molecule. He then showed how it picks up individual amino acids within a cell in a predetermined order and transports and combines them into specific proteins according to the cell's DNA molecule.

Holley was born in Urbana, Illinois, and studied chemistry at the University of Illinois before taking his doctorate in 1947 in organic chemistry at Cornell University, Ithaca, New York. He was on an American Chemical Society fellowship at Washington State College until 1948, when he moved to the New York State Agricultural Experiment Station, a branch of Cornell at Geneva. Later, in 1964, he transferred back to Ithaca as a professor of biochemistry. Although maintaining an affiliation with Cornell, he became a permanent resident fellow at the Salk Institute in La Jolla, California, shortly before winning the Nobel Prize. Holley received the Albert Lasker Award for Basic Medical Research in 1965, and his group was given the Distinguished Service Award of the U.S. Department of Agriculture.

HOOKE, ROBERT (1635–1703)

Robert Hooke was a versatile seventeenth-century English scientist who discovered the first law of elasticity for solid bodies, now known as Hooke's law. He was a brilliant experimenter who originated many scientific advances but perfected few; however, he was unrivaled in his time as an inventor of scientific instruments.

Hooke was born at Freshwater on the Isle of Wight and schooled at Westminster College and Christ Church, Oxford. Later he became an assistant to Robert Boyle, who was interested in the air pump invented by Otto von Guericke, seventeenth-century German natural philosopher. Hooke and Boyle devised improvements for the pump.

In 1662 Hooke was appointed curator of the newly founded Royal Society. In that capacity he was responsible for the experiments performed at the weekly meetings. He was elected a fellow of the society in 1663 and served as secretary between 1677 and 1683.

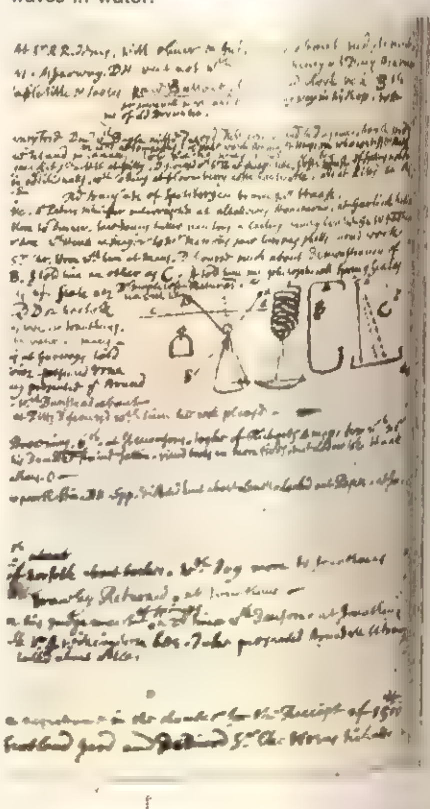
In 1665 he was appointed professor of geometry at Gresham College. He made astronomical observations and contributed to the development of astronomical instruments. Hooke built the first reflecting telescope, observed the rotation of Mars, and recorded one of the earliest known examples of a double star. He was the first to state clearly that the motions of the heavenly bodies must be considered a mechanical problem, and he approached the discovery of universal gravitation; but he lacked the mathematical prowess to give his thoughts quantitative expression.

Just as his theory of gravitation anticipated Isaac Newton's, his incomplete undulatory theory of light, which compared the spreading of light vibrations to that of the waves in water, anticipated that of Christiaan Huygens, founder of the wave theory of light.

In 1678 Hooke stated that the force tending to restore a ... ing or any elastic system to its equili... m position is proportional to the di... ce by which it is displaced from tha... ition. He had discovered earlier that ... l springs expand and contract abou... equilibrium position in equal peri... egardless of the length of the sw... his discovery of what is now know... hairspring made small and accurate ... ieces possible by eliminating the pe... .

In the field of bio... Hooke is remembered for discoverin... he porous structure of cork. Study ... cork under the microscope, Hooke ... und that a thin sliver was made of t... rectangular holes, which he called cells ... ecause they were similar to small, emp... rooms. The cells actually were dead ... mnants of struc-

Robert Hooke



In 1665 Robert Hooke ... shed one of his principal works, *Microg...* ... which was written in English rather th... tin and well illustrated. Among other thi... put forth a wave theory of light, compari... nt vibrations with waves in water.

tures that had been filled with a complex fluid while living. [illegible] term—*cells*—became a basic word i[illegible] biology.

Hooke invented [illegible] wheel barometer and discussed the [illegible]plication of barometrical indicatio[illegible] to meteorological forecasting. His [illegible]ipal publications are *Micrographia* [illegible], *Lectiones Cutlerianae* (1674–16[illegible] and *Posthumous Works* (1705).

HOOKER, SIR WI[illegible] JACKSON (1785–1865) and SIR JOSEPH [illegible]ON (1817–1911)

Sir William J[illegible] Hooker and his son Sir Joseph D[illegible] Hooker were English botanists w[illegible] increased the fund of knowledge in [illegible]ir field immensely during the ninete[illegible]h century. Sir William was the first [illegible]ector of the famous Royal Botanic G[illegible]s at Kew, Surrey. Sir Joseph succe[illegible] to the position upon his father's deat[illegible]

Sir William H[illegible]r advanced the understanding of l[illegible]r plants and ferns, algae, lichens, a[illegible]ngi. He published extensively on [illegible]pecialties. His son, who is famous [illegible]is botanical travels and studies on [illegible] geographical distribution of plants [illegible]emembered also for his espousal of [illegible]rles Darwin's views on the origin o[illegible]ies.

Sir William w[illegible]orn in Norwich, Norfolk, England, a[illegible] educated at the high school there. I[illegible]rst botanical expedition was to Icel[illegible] in 1809. He wrote an account of the [illegible]nd and its vegetation mainly from m[illegible]ory because his specimens were lost [illegible] a fire on the homeward voyage. He spe[illegible] most of 1814 on botanical tours of France, Switzerland, and northern Italy. In 1815 he married and settled at Halesworth, where he devoted himself to systematic botany and to the analysis of his world-renowned herbarium. Five years later he accepted the regius professorship of botany in Glasgow, Scotland. He was appointed director of the Kew Gardens in 1841 and expanded the collections sixfold in his twenty-four years as director.

His son Joseph was born at Halesworth, Suffolk, England, in 1817. He studied medicine at Glasgow University and became assistant surgeon and naturalist on Sir James Ross's expedition to Antarctica from 1839 to 1843. With his subsequent narrative of the expedition in *Flora Antarctica* (1844–1847), *Flora Novae Zelandiae* (1853–1855), and *Flora Tasmanica* (1855–1860), Sir Joseph became the foremost taxonomic botanist of his time.

From 1847 to 1851 he surveyed previously unexplored regions of India's northern frontiers. Sir Joseph's other expeditions included those to Syria and Palestine in 1860, to the Atlas Mountains in Morocco in 1871, and to the western United States in 1877.

He was appointed assistant director at the Royal Botanic Gardens in 1855 and director ten years later. He developed the gardens into an international center of scientific research. The herbarium still is arranged according to a plant classification created by Sir Joseph and the plant taxonomist George Bentham and published as the monumental *Genera Plantarum* (1862–1883).

Sir Joseph was a lifelong friend of Darwin, and it was to him that Darwin first revealed his theory of natural selection in 1844. In 1858 Hooker and Sir Charles Lyell, who established and interpreted the principles of geology, presented to the Linnaean Society the joint communication of Darwin and the naturalist A. R. Wallace on the origin of species. Sir Joseph was president of the Royal Society from 1873 to 1878; and among his many honors was the Order of Merit, awarded to him in 1907.

HOPKINS, SIR FREDERICK GOWLAND (1861–1947)

A British biochemist discovered early in the twentieth century that certain substances, later known as vitamins, are necessary for normal growth. For his pioneer investigations into nutritional chemistry, Sir Frederick Gowland Hopkins shared the 1929 Nobel Prize in physiology or medicine with the Dutch medical scientist Christiaan Eijkman. (*See* Christiaan Eijkman.)

Hopkins was born at Eastbourne, East Sussex, England. While studying chemistry at the University of London, he became an analytical assistant at Guy's Hospital and in 1888 began his medical studies. After taking his degree at the university in 1894, he joined the staff of the medical school at Guy's. In 1899 Hopkins became a lecturer in chemical physiology at Cambridge University, where he was appointed professor in 1914.

Hopkins realized early in his work that an understanding of proteins was an urgent need of biochemists. He made important contributions in that field with his researches into amino acids—basic components of proteins. He helped isolate the amino acid tryptophan and showed that some amino acids are not manufactured in the body but must be present in the diet for growth to take place. Finding that one sample of protein might support life while a seemingly identical protein would not, he deduced that one might contain a trace element—a substance needed in only minute quantities for growth. In 1906 he published preliminary reports on his experiments that proved the existence of essential amino acids and of food factors that were later named vitamins.

In a lecture he gave at the time, Hopkins theorized that rickets and scurvy might be caused by a lack of such necessary trace elements. New light was cast thereby on the work of Christiaan Eijkman, who had induced and cured beriberi experimentally but who did not understand that the disease results from a dietary deficiency rather than a causative germ.

In 1921 Hopkins isolated glutathione, an amino acid combination of critical importance for oxidation in living cells. Some scientists think that this was his most fundamental contribution; others point to his insistence that biological problems can be solved in chemical terms, as illustrated by his researches into lactic acid production in muscle. He laid the foundation for modern knowledge of the chemistry of muscular contraction by helping prove that lactic acid is a waste product of muscle contraction.

Hopkins was knighted in 1925. From 1930 to 1935 he served as president of the Royal Society of London, and in 1935 he was awarded the Order of Merit.

HOUSSAY, BERNARDO ALBERTO (1887–)

For his research on the role of the pituitary body in the metabolism of sugar the Argentine physiologist Bernardo Alberto Houssay won the 1947 Nobel Prize in medicine or physiology. He shared the prize with Carl F. Cori and his wife Gerty T. R. Cori, who studied the metabolism of glycogen. (*See* Carl Ferdinand and Gerty Theresa Radnitz Cori.)

Studies by Houssay showed that the metabolism of sugar can be prevented by hormones secreted by the anterior lobe of the pituitary. This lobe, in fact, produces a hormone with an effect opposite that of insulin.

Surgical techniques were used regularly by Houssay. He operated on dogs and frogs to remove the pituitary and other organs, and then he studied the blood sugar levels and other conditions. When he removed the pituitary from a diabetic animal, the severity of the disease was lessened. On the other hand, injection of pituitary extracts increased the severity of diabetes or, if none had existed, created a new case of the disease. Ordinarily an animal that does not have

a pancreas is diabetic; however, when Houssay injected pituitary extract into such animals, their diabetic condition became less severe.

Other areas of research for Houssay were digestion and the secretion of bile, the physiology of the circulatory and respiratory systems, and blood and immunological processes. He wrote *Human Physiology*, a textbook that was published in 1951.

Houssay was born in Buenos Aires, Argentina. At the age of seventeen he received a degree in pharmacy from the University of Buenos Aires, from which he also received his medical degree in 1911. He joined the faculty of the university's veterinary school in 1907 and was appointed professor of physiology in the medical school in 1919. He was dismissed from his post in 1943, however, because of political disagreements with the regime of dictator Juan Péron. He was reinstated within a short time but forced to leave again in 1946. He then did research on a private basis and became director of the Institute of Biology and Experimental Medicine, which he was instrumental in founding. In 1955, after Péron's downfall, he was reinstated as professor of physiology and director of the physiological institute at the university.

More than 25 universities bestowed honorary degrees on Houssay. He became a member of 38 academies and more than 300 scientific societies, including the U.S. National Academy of Sciences.

HUGGINS, CHARLES BRENTON (1901–)

The 1966 Nobel Prize in medicine or physiology was shared by two U.S. research scientists—Charles B. Huggins and Francis P. Rous. Independently, both had pioneered in early cancer research. (*See* Francis Peyton Rous.)

Huggins was honored for discovering the role that hormones play in specific forms of cancer. His research with dogs demonstrated that male hormones contribute to the development of cancer of the prostate. He found that such malignant growths in men can be controlled by castration or by the administration of female hormones and that breast cancer in women can be curbed by the use of male hormones. His work marked the first successful use of medication to cure cancer in human beings.

Huggins was born in Halifax, Nova

Charles Huggins

Scotia, Canada, and graduated from Acadia University, Wolfville, Nova Scotia, in 1920. After receiving a medical degree from Harvard University in 1924, he worked at the University of Michigan and at the University of Chicago, where he became professor of surgery in 1936 and the William B. Ogden Distinguished Service Professor and director of the Ben May Laboratory in 1951. He was elected to the National Academy of Sciences in 1949 and was given the Passano Foundation Award in 1955.

HUMBOLDT, FRIEDRICH HEINRICH ALEXANDER VON (1769–1859)

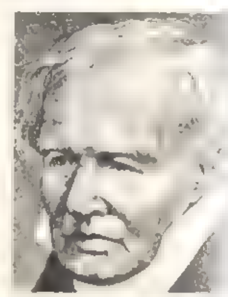
One of the most famous men in Europe during the late eighteenth and early nineteenth centuries was the German naturalist and world explorer F. H. Alexander von Humboldt. He traveled through Europe, South America, and central Asia, collecting a fantastic number of biological and geological specimens. The culmination of his work was an attempt to present the first complete, coherent view of the physical world as a whole; and he is considered by some as the founder of physical geography.

Humboldt was born in Berlin and educated mainly at the University of Göttingen and at the mining school in Freiburg. Although his father, a Prussian nobleman, intended that he should enter politics, Humboldt was interested in botany and had a profound urge to travel and explore. In 1790 he made his first journey: through western Europe with a naturalist who had been on a voyage around the world with Captain Cook.

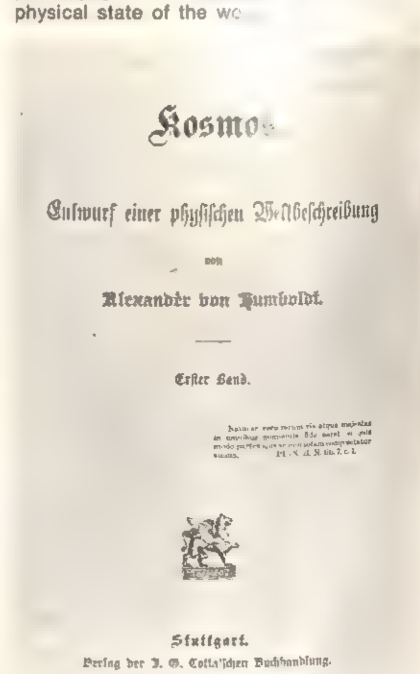
For several years Humboldt worked as an inspector of mines at Bayreuth, where, with his liberal, humanitarian tendencies, he devoted himself to improving conditions for the miners. Then in 1796, on the death of his mother, he came into an inheritance that allowed him to travel.

In 1799 he embarked on a five-year exploratory trip of South America. Starting from Cumaná, Venezuela, where he had first landed, he went on to Caracas and then proceeded to explore the course of the Orinoco River and the source of the Amazon, after which he visited Cuba for a few months. Returning to the mainland of South America, he traveled along the Cordilleras from Colombia to Peru. En route, in Ecuad[illegible] he climbed almost 19,000 feet up v[illegible]ic Chimborazo, setting a long-stan[illegible] mountain-climbing record.

Humboldt's acc[illegible]ments on these expeditions were [illegible] He studied the occurrence of vol[illegible] the Americas and, noting that th[illegible]pear in straight lines, believed th[illegible] follow a flaw in the Earth's cru[illegible] measured the temperatures of [illegible] current off South America's w[illegible]t—the current that was later na[illegible]his honor; and he discovered th[illegible]ing properties of Peruvian guano [illegible]was largely responsible for its intr[illegible]on into Europe. He was the first to s[illegible]the rate of temperature decrease[illegible]creases in relation to the height [illegible] sea level, and



Alexander von Humboldt



Kosmo

Entwurf einer physischen Weltbeschreibung

von

Alexander von Humboldt.

Erster Band.

Stuttgart.

Verlag der J. G. Cotta'schen Buchhandlung.

In his most importan[illegible] *Kosmos* (1845–1862), which was an [illegible]o show a unity among the complexit[illegible]ture, Alexander von Humboldt summa[illegible] experience and philosophy and desc[illegible]he history and physical state of the wo[illegible]

he also noted the decline in the Earth's magnetic force close to the Equator.

After spending a year in Mexico and visiting the United States, Humboldt returned to Europe in 1804 and began writing an account of his journey. This project took him twenty years and was published in thirty volumes. For most of that time he lived in Paris. After his inheritance was gone, he moved back to Prussia, where he served the king as a diplomat.

In 1829, at the invitation of the Russian czar, Humboldt [illegible] about six months exploring central [illegible] traveling over the Ural Mountains [illegible] the Chinese border and back by [illegible] the Caspian Sea. This exploration [illegible] the completion of meteorological [illegible] for the isothermal world map, a [illegible] of the orographic configuration of central Asia, and the discovery of diamonds in the Urals.

When he [illegible] his mid-seventies, Humboldt began his most important written work, the *Kosmos*, which was actually an encyclopedia of geography and geology in which he tried to present a unified, [illegible] of the Earth. He just managed to complete it shortly before his death, the fifth and last volume being published posthumously.

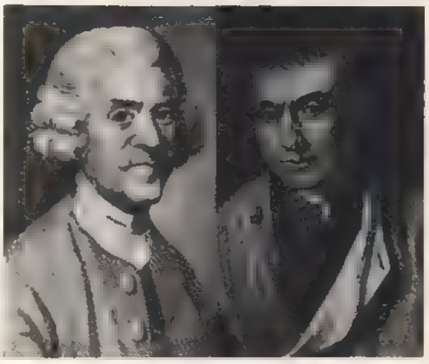
HUNTER, JOHN (1728–1793) **and WILLIAM** (1718–1783)

Two brothers, John and William Hunter, were responsible for major advances in the teaching of anatomy and in the practice of obstetrics and surgery in Great Britain during the eighteenth century. John Hunter was considered by many to be the founder of scientific surgery and became the greatest surgeon of his time. His older brother William raised the practice of obstetrics from midwifery status to that of a specialized branch of the regular medical profession. Both John and William were born at Long Calderwood, East Kilbride, Lanarkshire, Scotland.

William was educated at the University of Glasgow and later studied medicine in Edinburgh and London. He received his medical degree from Glasgow, however, in 1750.

Four years earlier he had begun his long career of teaching anatomy and surgery. Almost single-handedly he reformed the teaching of anatomy in Great Britain, introducing the practice of having each student dissect a cadaver.

In 1748 he was appointed surgeon-accoucheur at Middlesex Hospital, and the following year he served in the same capacity at the British Lying-In Hospital. By 1756 he had given up the practice of surgery altogether and was concentrating on obstetrics. The leading obstetrician of his day, in 1762 he was consulted regarding the pregnancy of Queen Charlotte Sophia and in 1764 was appointed physician extraordinary to the queen.



William and John Hunter

He was admitted to the College of Physicians in London in 1756, was elected a fellow of the Royal Society in 1767, and became the first professor of anatomy at the newly established Royal Academy in 1768. His greatest work, which required about thirty years of preparation, was *Anatomy of the Human Gravid Uterus* (1774).

John was the youngest of ten children. He was never interested in books or reading and consequently never acquired a university education, becoming instead a cabinetmaker's assistant.

In 1748 he went to London to assist his brother William with dissections and held that position for eleven years, gaining a knowledge of anatomy in the meantime. During the summers of 1749 and 1750 he also studied surgery at Chelsea Hospital and at Saint Bartholomew's.

He became a surgeon pupil at Saint George's Hospital in 1754, worked as house surgeon in 1756, and was elected surgeon to Saint George's in 1758. As staff surgeon with the British army in Portugal from 1760 to 1763, he learned much about gunshot wounds. In the latter year he returned to London and set up a surgical practice. In 1768 he began teaching at Saint George's Hospital.

Although not so eloquent a speaker as his brother, after 1773 he began lecturing on surgery. He also took in house pupils, of whom the most famous was Edward Jenner. In 1776 he was appointed surgeon extraordinary to George III and in 1790 surgeon general to the army and inspector general of hospitals.

John Hunter's curiosity encompassed a wide range of anatomical and biological subjects. He did research on bees, the descent of testes in the fetus, the course of olfactory nerves, the formation of pus, placental circulation, the function of the lymphatics, the coagulation of blood, digestion in hibernating snakes and lizards, the structure of whales, and the growth of deer's antlers. He also found that small arteries increase in size when the circulation is cut off in larger arteries.

His greatest contribution to surgical techniques was the operation for aneurysm that he devised in 1785, ligating the artery above the affected area. He also made the first successful graft of tissue on an animal.

While doing research on venereal diseases in the 1760s, he experimented with self-inoculation and contracted syphilis. This may have been responsible for much of his illness in later life, perhaps even contributing to his death.

His *Natural History of the Human Teeth* became the scientific basis for dental anatomy and pathology. Among his other books are *A Treatise on the Venereal Disease, Observations on Certain Parts of the Animal Oeconomy,* and *A Treatise on Blood, Inflammation, and Gun-shot Wounds.*

He was elected a fellow of the Royal Society in 1767 and was awarded its Copley Medal in 1787. That same year he became a member of the American Philosophical Society.

Both John and William were collectors and built up extensive museums. In addition to his physiological specimens, William collected coins, medals, minerals, shells, corals, and rare books. After his death his museum was eventually turned over to the University of Glasgow. John's collection reflected his interest in comparative anatomy and was intended to present an encylopedic view of life. It included specimens of healthy and diseased organisms, animal and plant alike, and also fossils. One of the most interesting exhibits was the skeleton of a giant, seven feet, seven inches tall. His museum was purchased by the British government after his death but was almost totally destroyed by bombs during World War II.

During the early years of their careers the two brothers worked closely together, but later there developed resentment between them. William claimed some of John's discoveries as his own; and in 1780, after a public dispute regarding research done on uteroplacental circulation, the brothers ceased communicating with each other altogether. Although John was the attending physician when William was dying, the breach between them was never completely healed.

HUTTON, JAMES (1726–1797)

James Hutton, eighteenth-century natural philosopher, founded geology as an organized science. The significance of sedimentary rock was dawning in his time, but an organized field of study did not exist. One of the powerful inhibitors was the Bible, according to which the Earth was only about 6,000 years old.

Hutton observed the stratigraphical conformity in the field, noted the igneous intrusions, and formulated the principle of the geological cycle. He realized from careful study that some rocks are compressed sediment, that some are brought to the surface by volcanic action, and that exposed rocks are worn away by wind and water. His research caused him to deduce what is now a basic tenet of geology—the uniformitarian principle, which states that natural agents at work on and within the Earth have operated with general uniformity through aeons. This doctrine was diametrically opposed to the doctrine of catastrophism commonly held in Hutton's day. According to that concept, every major feature, such as a mountain or a chasm, was formed abruptly by catastrophic forces. Hutton, however, saw that in the edges of folded strata are visible "the ruins of an older world."

Hutton had a varied career before he became preoccupied with geology. He was born in Edinburgh, Scotland. At seventeen years of age he was apprenticed to a lawyer, but Hutton was so interested in his spare-time chemical experiments that he decided to study medicine. After three years at Edinburgh University he completed his training at the university in Leiden, Holland. After taking his medical degree in 1749, Hutton turned to agriculture. While he farmed, though, his thoughts turned to the rocks under the soil. A successful business venture—the manufacture of ammonium chloride—enabled him to settle in Edinburgh and to follow his various scientific pursuits from 1768 onward.

He wanted to trace the origin of minerals and rocks in order to arrive at a clear understanding of the Earth's history. He communicated his views in 1785 to the newly established Royal Society of Edinburgh in a paper titled "Theory of the Earth; or An Investigation of the Laws Observable in the Composition, Dissolution, and Restoration of Land upon the Globe." It was published in the society's *Transactions*. His work gained little recognition, however, until the publication in 1802 of John Playfair's *Illustrations of the Huttonian Theory*, a clear exposition of Hutton's ideas. Those ideas gained wide acceptance in the mid-nineteenth century when the British geologist Sir Charles Lyell published his landmark works on geology.

Hutton's works include *Dissertations on Different Subjects in Natural Philosophy* (1792), in which he discussed the nature of matter, fluidity, cohesion, light, heat, and electricity. In his closing years Hutton expanded and republished his *Theory of the Earth*, of which two volumes appeared in 1795. A portion of a third volume was edited in 1899.

HUXLEY FAMILY

Fundamentally important contributions in a wide range of scientific fields distinguish the British Huxley family. The Huxleys were highly successful, moreover, in relating science to the humanities and in communicating with their nonscientific readers.

Outstanding members of the family include Thomas Henry Huxley (1825–1895); his eldest son, Leonard Huxley (1860–1933); and his grandsons, Sir Julian Sorell Huxley (1887–), Aldous Leonard Huxley (1894–1963), and Andrew Fielding Huxley (1917–).

Thomas Huxley is probably best known for supporting Charles Darwin's theory of evolution and extending it to include humans; but besides zoology and anthropology, he studied and wrote about botany and geology, including paleontology. In his clear literary style he produced ten scientific textbooks and many essays and articles. After intensive study of life in tropical seas he concluded that the hydra and medusa are two forms in the life cycle of one animal; and he established the class Hydrozoa, which unites the hydroid polyps with the medusae. In later research he demonstrated the affinity of reptiles with birds [illegible]

Thomas Huxley

He introduced labo[illegible]tory work into the study of biology; a[illegible] he held that in religion, as well as in [illegible]r areas, theories should be based on [illegible]tual observation. For his own philo[illegible]hical views he coined the word *agn[illegible]icism.*

Thomas Huxley w[illegible] born in Ealing, Middlesex, England [illegible] seventh child of a schoolmaster. [illegible]t for two years of schooling, Thom[illegible]as mostly self-taught until he be[illegible]gular medical studies at Charing [illegible]s Hospital in London. In 1845 h[illegible]lished the first of his many resea[illegible]apers. Its subject was the previ[illegible]nknown layer in the inner sheath [illegible], subsequently identified as Huxle[illegible]

In 1846 Thomas [illegible]y sought and received an appoi[illegible] in the Royal Navy. His chief, Si[illegible]ichardson, an Arctic explorer and [illegible]list, procured for him the post o[illegible]on on H.M.S. *Rattlesnake*, which [illegible]about to leave for surveying work i[illegible]rres Strait, between northern Aus[illegible]a and Papua. Huxley's brilliant resea[illegible] on marine life during the four-year [illegible] resulted in his election as a fellow o[illegible] Royal Society in 1851. He was awar[illegible]s Royal Medal in the following yea[illegible]

After leaving nava[illegible]vice in 1854, Thomas Huxley wa[illegible]nted lecturer in natural history at [illegible]hool of Mines (later the Royal C[illegible]f Science) in London. Much in d[illegible] he eventually left research for pub[illegible]ty, serving on at least ten royal co[illegible]ions between 1862 and 1884. He w[illegible]cretary of the Royal Society from [illegible] to 1880 and president from 1883 to [illegible]85. As a member of the newly forme[illegible] London School Board from 1870 to 1872, he worked against scholastic methods based on memorizing and fought for a rounded course of studies.

In 1855 Thomas Huxley married Henrietta Anne Heathorn, whom he had met in Sydney, Australia. Their son Leonard became a classical scholar and writer on scientific, literary, and educational subjects. Leonard's son Julian achieved fame as a biologist and a writer on science and philosophy. Like his grandfather, Julian was an active supporter of Darwin's theory of evolution. He influenced the development of embryology with his studies of the relative growth rates of parts of organisms.

Julian was born in London and educated at Balliol College, Oxford. His important positions included those of assistant professor at Rice Institute, Houston, Texas, 1913 to 1916; fellow at New Col-

lege, Oxford, 1919 [illegible] 1925; professor at King's College, U[illegible]versity of London, 1925 to 1927; and se[illegible]retary of the Zoological Society of Lo[illegible]n, 1935 to 1942.

Among the influ[illegible]al books that Julian Huxley wrote, co[illegible]ored, or edited are: *The Individual i[illegible] Animal Kingdom* (1912); *Religio[illegible]ithout Revelation* (1927); *The Scie[illegible]f Life* (1931); *Problems of Relati[illegible]owth* (1932); *The Captive Shrew a[illegible]Other Poems of a Biologist* (1932); [illegible] *Elements of Experimental Embryo[illegible]* (1934); *The New Systematics* (19[illegible]) *The Uniqueness of Man* (1941); *E[illegible]on, the Modern Synthesis* (1942); [illegible]*chstone for Ethics, 1893–1943* (19[illegible]) *Soviet Genetics and World Science* [illegible]49); *Evolution as a Process* (1954) [illegible]d *Toward a New Humanism* (19[illegible]

Julian Huxl[illegible] as elected a fellow of the Royal [illegible]ty in 1938 and was knighted in 19[illegible] rom 1946 to 1948 he served as the fi[illegible]irector general of the United Natio[illegible]lucational, Scientific, and Cultural [illegible]ization (UNESCO). He was quote[illegible] aying that he wanted to be rememb[illegible] not primarily for his specialized sc[illegible] work, but as a generalist to who[illegible]ing human and nothing in externa[illegible]ure was alien.

Julian's bro[illegible] Aldous was born at Godalming, S[illegible]y, and educated at Balliol also. He b[illegible]e renowned as a witty and prolific n[illegible]ist, essayist, and writer of biography, [illegible]ama, and verse. His celebrated book [illegible]*ave New World* (1932) reflected a pes[illegible]mistic vision of the future that was grounded in his distrust of current trends in politics and applied science. The utopian novel *Island* (1962) was his last major work.

In 1963 Andrew Fielding Huxley, half brother of Julian and Aldous, shared the Nobel Prize in physiology or medicine with Alan L. Hodgkin and Sir John C. Eccles for research in nerve conduction. Andrew Huxley is notable also for his contributions to the understanding of muscle contraction. (*See* Sir John Carew Eccles; Alan Lloyd Hodgkin.)

Andrew, the son of Leonard Huxley and his second wife, was born in Hampstead, London. He was educated at University College School and Westminster School, both in London, and at Trinity College, Cambridge, where he was a fellow from 1941 to 1960 and director of studies from 1952 to 1960. During World War II he did operational research for the antiaircraft command (1940–1942) and for the Admiralty (1942–1945). Afterward he was successively demonstrator, assistant director of research, and reader in experimental biophysics in the Department of Physiology at Cambridge. In 1960 he became Jodrell Professor of Physiology at University College, London.

His research work was concerned mostly with the physical and chemical analyses of the phenomena involved in excitation in a peripheral nerve fiber. With Hodgkin he developed mathematical equations for describing the nerve impulses. He was elected to the Royal Society in 1955.

HUYGENS, CHRISTIAAN (1629–1695)

The Dutch mathematician, astronomer, and physicist Christiaan Huygens was a man of such extraordinary accomplishments that his biographers disagree on which of his contributions was the greatest. He is known best, perhaps, for his wave theory of light; but some call his invention of the first operative pendulum clock an even greater achievement.

Huygens was born in The Hague. As a son of Constantijn Huygens, a high government official and the most versatile man of letters and science in the Dutch Renaissance, Christiaan was reared in an intellectual atmosphere. Before concentrating on the study of mathematics and science, he studied jurisprudence at the universities of Leiden and Breda and traveled for a time.

Christiaan Huygens

He had long been interested in drawing and making mechanical models when, at the age of twenty-six, he began to work with his brother on improving the telescope and subsequently developed a new method of grinding and polishing lenses. Shortly thereafter he detected a satellite of Saturn and became the first person to observe the true form of Saturn's rings. He was also, in 1656, the first effective observer of the Orion nebula. Huygens' need for an exact measure of time in making astronomical measurements led to his application of the pendulum as a time controller. The *Horologium*, describing the requisite mechanism, was published in 1658.

In 1663 Huygens was elected a fellow of the Royal Society of London. His reputation spread throughout Europe, and in 1666 King Louis XIV induced him to come to France, where he became a foundation member of the French Academy of Sciences. In 1672 he met Gottfried W. Leibniz, one of the major systematic thinkers of modern times, whom he gave lessons in mathematics and whose first paper on differential calculus he presented to the Academy of Sciences in 1674. After his return to Holland in 1681, Huygens produced lenses of enormous focal distance and constructed an eyepiece that is still known by his name.

Huygens' greatest work, the *Horologium oscillatorium* (1673), included his determination of the true relation between the length of a pendulum and the time of its oscillation and stated the theorems on centrifugal force in circular motion that helped Sir Isaac Newton formulate his law of gravitation.

In the course of his research in physical optics Huygens developed the wave theory of light, which already had been adopted by the English scientist Robert Hooke in 1665. According to Huygens, as stated in his *Traité de la lumière*, written in 1678 and published at Leiden in 1690, all the points of a wave front originate secondary waves, and transmission of the original wave can be plotted from the combined effects of these secondary waves. This is the well-known principle of Huygens, by means of which he was able to prove the fundamental laws of optics.

JACOB, FRANÇOIS (1920–   )

Research producing new insight into the regulatory functioning of cells won for French biologist François Jacob a share of the 1965 Nobel Prize in medicine or physiology. His co-winners were André Lwoff and Jacques Monod. (*See* André Lwoff; Jacques Monod.)

Jacob's major research was concerned with the action of genes, the components of cells that determine hereditary characteristics and control the production of proteins. He and his colleagues worked on the metabolism of microorganisms and proposed the existence of a class of regulatory genes that serve to control the action of the genes that direct enzyme synthesis. The genes that direct the synthesis of enzymes are suppressed by chemical signals from regulator genes; but when the signals are interrupted, the structural and operator genes begin to produce enzymes.

Jacob was born at Nancy, France. During World War II he was a member of the Free French Forces and was awarded the croix de guerre for bravery. Resuming his medical studies after the war, he received a medical degree in 1947 and a doctorate in science in 1954. Meanwhile, in 1950, he had joined the Pasteur Institute of Paris, becoming head of its Department of Microbic Genetics in 1960. He was appointed professor of cellular genetics at the Collège de France in 1964.

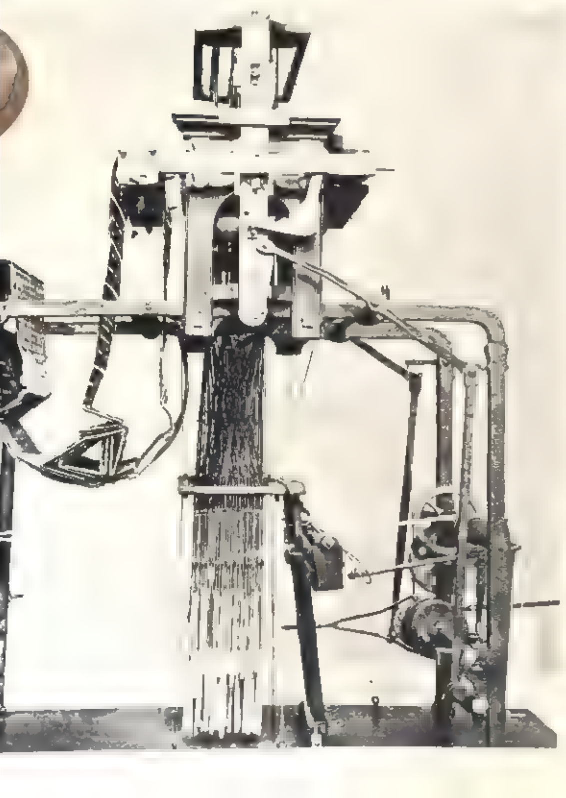
JACQUARD, JOSEPH MARIE
(1752–1834)

The Jacquard loom for weaving complicated patterns evolved from an attachment invented by Frenchman Joseph Marie Jacquard early in the nineteenth century. The innovation gave impetus to the silk-weaving industry and reduced the cost of textiles having a woven pattern.

Jacquard was born at Lyons, France, a great silk-weaving center. From early childhood he was familiar with the drawloom, though he was doing typefounding and cutlery work when he formed the idea for his loom attachment. Amid the excitement and upheaval of the French Revolution, Jacquard's idea was forgotten; but afterward he constructed his loom and demonstrated it at the industrial exhibition in Paris.

The greatest technical problem in silk pattern weaving was the awkward and expensive drawloom. In 1803 Jacquard was called to Paris to study and work at the Conservatoire des Arts et Métiers in order to perfect his weaving machine. There, a loom developed in the eighteenth century by Jacques de Vaucanson suggested improvements that Jacquard proceeded to apply to his own machine. The Jacquard loom eliminated the drawboy and automated the pattern weaving.

Before it was widely adopted, Jacquard suffered physical violence and the burning of his machines at the hands of Lyons silk weavers, who feared for their livelihood. The loom's advantages, however, brought about its general acceptance; and by 1812 there were 11,000 drawlooms of the Jacquard type in use in France. Although the loom had been declared public property in 1806, Jacquard was rewarded with a pension and a royalty on each machine. By 1816 his machines were in use in Britain, where they were quickly adapted to the cotton and linen industries and by weavers of shawls. In 1819 he received a medal and the Cross of Honor, and six years after his death a statue in his honor was erected in Lyons.



By adapting features of a loom by Jacques de Vaucanson, Joseph Jacquard perfected his own loom, which automated the weaving of patterns and thereby reduced time and costs.

JAMES, WILLIAM (1842–1910)

The first major U.S. psychologist, William James, was the leader of a movement known as pragmatism. After publishing his theories in 1907, he became recognized as the foremost philosopher of the time.

James was born in New York City, the son of theologian Henry James and brother of novelist Henry James. He received his early education from private tutors in the United States and Europe. At first he appeared interested in studying art; but he abandoned it and entered Harvard University's Lawrence Scientific School to study chemistry, anatomy, and related subjects. He went on to the Harvard Medical School, but he interrupted his studies for rather extended periods, first to go with the Brazilian zoological expendition of Jean Louis Agassiz and then to study psychology in Germany. In 1869, however, he received his medical degree; but because of ill health he was unable to begin practice.

Three years later, in 1872, James joined the faculty of Harvard, an association that was to continue until his retirement in 1907. He began his career as an instructor in physiology; but, fascinated as he was with the human mind, he switched to psychology in 1876. Viewing psychology, then a new discipline, as an experimental science based as much on physiology as it was on philosophy, he set up the first demonstrational psychological laboratory in the United States. Among his students at this time was Gertrude Stein, who said James was a great influence on her first book, *Three Lives*.

William James

In 1878 James signed a contract to write a modern textbook on psychology. He intended to complete it in two years, but it took him twelve. When it was finally produced in 1890 it was more than a textbook—it was a two-volume treatise called *The Principles of Psychology*, hailed as both a great scientific achievement and a great literary work. It was translated into French, German, Russian, and Italian, as well as condensed into one volume, which was the leading standard college psychology textbook for many years. The work established psychology as a functional science and James as one of the foremost minds of the period. It developed the idea of stream of consciousness in thought, defended free will, and firmly linked mental activity with the biological sciences.

The decade following the publishing of this great work can be described as James's religious period. He turned to religion in his thinking, concentrating on the nature and existence of God, free will and determinism, and the values of life, and became a popular lecturer and author. His published works during this period include *The Will to Believe and Other Essays in Popular Philosophy* (1897), *Human Immortality* (1898), *Talks to Teachers on Psychology and to Students on Some of Life's Ideals* (1899), and *The Varieties of Religious Experience* (1902). All of these deal with some aspect of religion.

The next period in James's life involved his development of pragmatism. The general idea of pragmatism is that the meaning of any idea must be looked for in its practical application, thought must function to guide a person to action, and truth must be tested by the consequences of belief. In 1906 James published *Pragmatism: A New Name for Old Ways of*

Thinking, and in 19[illegible]9 some of his lectures on pragmatism we[illegible] published under the title *A Pluralisti[illegible]iverse*. The view expressed in these [illegible]res was that the universe is constan[illegible] changing and that nothing remains [illegible]tant. To James absolute truth can e[illegible]ly in a fixed, ordered universe in wh[illegible]ch event is predestined. Becausc [illegible]loes not live in such a universe—he [illegible] not know what the future holds—[illegible]st use his mind to help build a b[illegible]ocial order of things. Several of his [illegible]r works on pragmatism—"Does Co[illegible]ousness Exist?," "The Thing and Its [illegible]tions," and "The Experience of A[illegible]ty"—appeared in the *Journal of Phil[illegible]y* and were published in 1912 as *Essa[illegible] Radical Empiricism*.

JAUREGG. Se[illegible] Wagner von Ja[illegible]gg, Julius.

JEANS, SIR JA[illegible]S HOPWOOD (1877–1946)

The English [illegible]thematician and physicist Sir Jame[illegible]pwood Jeans became well known fo[illegible] popular books on science, such as [illegible] *Universe Around Us* (1929) and [illegible]*ugh Time and Space* (1934). By a[illegible]ng mathematics to astronomy and [illegible]ics, he made serious contribution[illegible]ese sciences. He also gave mathe[illegible]proofs for the law of the equiparti[illegible]energy and the law of the distribut[illegible] the velocity of molecules and de[illegible]d a formula regarding the distribu[illegible]f energy emitted by a blackbody.

In the area [illegible] astronomy he disproved Pierre Laplac[illegible]'s theory of the origin of the solar system, which contended that the solar system was created from a swirling mass of gases. Jeans held that a passing star had pulled a huge cigar-shaped mass from the sun. According to Jeans this mass separated into the planets, with the largest planets, Jupiter and Saturn, being formed from the thickest middle part. His theory was highly unlikely, but his speculations gave rise to several newer and more sophisticated cosmogonies. He also did work on problems regarding the formation of double stars, on spiral nebulas, and on stellar energy and developed a theory about dwarf and giant stars.

Jeans was born in London and studied mathematics at Trinity College, Cambridge, graduating second in his class in 1898. At Cambridge he was Smith's prizeman in 1900 and became a fellow of Trinity College in 1901. Four years later he was appointed professor of applied mechanics at Princeton University, in New Jersey. From 1910 to 1912 he was a lecturer at Cambridge but then gave up teaching to devote himself to full-time research.

He was elected a fellow of the Royal Society in 1906, knighted in 1928, and awarded the Order of Merit in 1939. For his *Problems of Cosmogony and Stellar Dynamics* (1919) he was awarded the Adams Prize. His other published works include *Dynamical Theory of Gases* (1904), *Mathematical Theory of Electricity and Magnetism* (1908), *Radiation and the Quantum Theory* (1914), and *Atomicity and Quanta* (1926).

Sir James Jeans

JENNER, EDWARD (1749–1823)

One of the great discoveries in medical history, vaccination against smallpox, was made by an English physician, Edward Jenner, late in the eighteenth century. It was the first successful immunizing procedure against any disease, and for almost a century it was the only one.

Jenner was born at Berkeley, Gloucestershire. Although his interests ranged from music to poetry and natural history, it was the study of medicine that he pursued seriously, first with a surgeon of Sodbury, in the vicinity of Bristol, and then, beginning in 1770, with the great surgeon and naturalist John Hunter in London. During this period Jenner was employed to prepare and arrange zoological specimens from the first (1771) voyage of Captain James Cook, the English navigator and explorer. In 1792 Jenner received his medical degree from Saint Andrews University, Scotland.

Edward Jenner's inoculation of an eight-year-old boy in 1796 with matter from cowpox blisters was the first successful immunizing procedure, or vaccination.

When Jenner began to practice medicine, the idea of vaccination matured in his mind. He was familiar with the local tradition that persons who contracted cowpox were immune to smallpox—a widespread, ravaging, and often fatal disease. Cowpox, or vaccinia, is a mild, eruptive disease of cattle that is caused by a strain of the same virus that causes smallpox. Extremely contagious, it may be contracted by persons who handle infected cows. Jenner ascertained that cowpox protects from smallpox only when cowpox is communicated at a particular stage. In May 1796 he had his first opportunity to test his theory of vaccination. He inoculated an eight-year-old boy with matter from the cowpox blisters on the hands of a milkmaid. Two months later he inoculated the boy with smallpox matter, but the disease did not follow. In 1798 he made a similar test with equally happy results and published his *Inquiry into the Cause and Effects of the Variolae Vaccinae*.

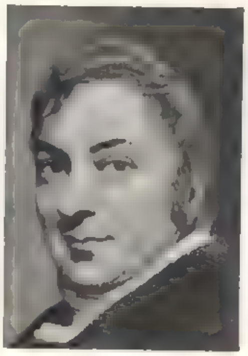
Jenner's vaccination with cowpox virus superseded the old inoculation, or variolation, in which the smallpox virus itself was implanted. This procedure conferred immunity after causing what usually—but not always—was a mild case of smallpox. Although the fatality rate was much lower than that of naturally acquired smallpox, the method spread the disease to the unprotected. Such inoculation had long been practiced in the Orient and the Near East, and it had been popularized in England early in the eighteenth century.

Vaccination was slow to gain approval of the medical profession in London, and its adoption was further delayed by the advocacy of George Pearson, who supplied a defective vaccine that often produced, not the mild disease described by Jenner, but severe eruptions that resembled smallpox. After Jenner's vaccine was used with excellent results in Vienna, Austria, in 1800, it gained more support in London. In 1802 Parliament voted a grant of £10,000 for Jenner, who was vaccinating the poor—as many as 300 daily—without charge, and five years later it granted him an additional £20,000.

In 1803 the Royal Jennerian Society

was established to encourage proper vaccination. In its first eighteen months 12,000 persons were inoculated, and the average number of deaths from smallpox fell from 2,000 to 600. The society disbanded in 1808 when the national vaccine establishment was founded.

The practice of vaccinating spread throughout Europe and the Americas. In



Edward Jenner

1807 Bavaria made vaccination compulsory, and other countries eventually followed. In medically advanced countries smallpox has not been a problem since Jenner's time.

Jenner received honorary degrees from Oxford and Harvard universities. In 1788 he was elected a fellow of the Royal Society, partly for his observations about the cuckoo—he was always a naturalist. His last paper, "On the Migration of Birds," was presented to the Royal Society and appeared in its *Philosophical Transactions* in 1823.

JENSEN, JOHANNES HANS DANIEL (1907–   )

One of the scientists who worked out the description of nuclear-shell structure was Johannes Jensen, a German physicist. At first he worked independently but later collaborated with Maria Mayer. For his contribution to knowledge about atomic nuclei Jensen shared the 1963 Nobel Prize in physics with Mayer and Eugene Wigner. (*See* Maria Goeppert Mayer; Eugene Paul Wigner.)

Along with several colleagues Jensen constructed a model of a nuclear shell in which the nucleons moved in definite orbits. Nucleon-scattering experiments later confirmed the validity of the model and its characteristics. In 1955 Jensen and Mayer together wrote *Elementary Theory of Nuclear Shell Structure*, explaining their nuclear-shell hypothesis.

In other areas of physics Jensen worked on the recoil distribution of nuclear radiation in molecules and interpreted the giant resonance in the nuclear photoeffect. He also did quantum mechanical studies of ionic lattices and investigated the behavior of matter under high pressure.

Jensen, the son of a gardener, was born in Hamburg, Germany. He was educated at the University of Hamburg, receiving his doctorate in physics in 1932. From 1936 to 1941 he taught physics at Hamburg and then was appointed associate professor at the Institute of Technology in Hanover, remaining there until 1949, when he became a professor at the University of Heidelberg; in 1954–1955 he was also the dean of the science faculty. He was a visiting professor at the University of Wisconsin in 1951 and also became a fellow of the Institute for Advanced Study located at Princeton, New Jersey.

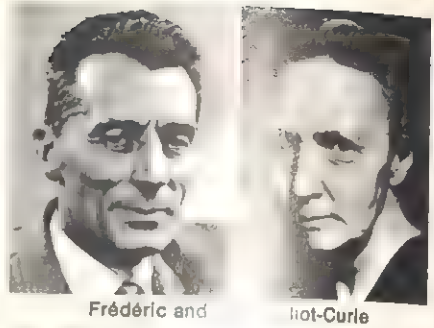
JOLIOT-CURIE, FRÉDÉRIC (1900–1958) **and IRÈNE** (1897–1956)

Continuing the work pioneered by her distinguished parents, Irène Joliot-Curie and her husband, Frédéric, were awarded the 1935 Nobel Prize in chemistry for artificially producing radioactive elements. It was the family's third Nobel Prize. (*See* Pierre and Marie Curie.)

Irène was born in Paris a year after the discovery of radioactivity. The elder daughter of Marie and Pierre Curie, who discovered radium, she grew up in a scientific atmosphere, was educated at the Sorbonne, and became her mother's assistant at the Radium Institute in Paris. There she acquired her familiarity with the radioactive elements. In 1925 she presented her doctoral thesis on the radiation properties of polonium, the first radioactive element discovered by her parents. That same year she met a young engineer, Frédéric Joliot, who had joined the staff at the institute. They were married in 1926 and worked as a team for ten years. Frédéric added his wife's name to his own to perpetuate the illustrious name of Pierre and Marie, who had no sons.

Frédéric Joliot was born in Paris. His family background was not scientific, but his interests were. In his first five years at the Radium Institute he mastered experimental techniques and developed his abilities. With his study of the electrochemistry of the radioactive elements as its basis, Frédéric obtained his doctorate in 1930.

Frédéric concentrated on the chemical aspects of radioactivity, and Irène studied the physical. Marie Curie had been farsighted in stockpiling intense radioactive



Frédéric and ... liot-Curie

sources for medical ... ment and nuclear research, and this ... ontributed immensely to the su ... experiments by Irène and Frédéri...

The couple's ou ... discovery revealed that when ... ments, such as aluminum, are bo ... d with alpha particles emitted b ... ium, these elements in turn emit ... particles, the emission continuin ... after the bombardment stops. Th ... very prepared the way for many ... ements in nuclear physics, chem ... nd biology. It was an important ... vard the solution of how to relea ... energy of an atom. The Nobel a ... d other honors brought to an end ... liot-Curie collaboration because ... new responsibilities to assume

Irène succeeded ... ther, who had died in 1934, as di ... f the Radium Institute and profe ... dioactivity on its faculty. In 193 ... ecame undersecretary of scienti ... search in the French cabinet. With ... continuing research she contribut ... the discovery of chain atomic disin ... ation. Frédéric was appointed to a ne ... hair of nuclear chemistry at the Coll ... le France. He

The instruments used b... Joliot-Curies to artificially produce radio... ve elements are displayed at the Radium Institute in Paris. (Also, see photograph, p. 78.)

pursued his resear on the fission of uranium and the bic cal applications of artificial radioacti lements.

With the onset orld War II, Irène Joliot-Curie took ge in Switzerland with their two ren. Frédéric remained in Franc take an active part in the resistanc ement. In 1944 he was appointed d r of the French National Center o entific Research in Paris, and in 194 was made high commissioner for at energy.

After the war served as professor and director of dium laboratory at the Sorbonne 1947 to her death. Frédéric devot mself largely to the establishment o rench atomic energy industry. In 19 was removed from his post with t nch Atomic Energy Commission fo utspoken dislike of many clerical olitical institutions. Irène, who hel ame views, was dismissed the foll year from her post with the comm Within a few years she died of leul n Paris, and Frédéric succeeded to l air at the Sorbonne. Deeply conce bout world peace, he was active in g the United Nations Atomic Ener ommission and the United Natic lucational, Scientific, and Cultural ization (UNESCO). When, after a acted illness, he died, the Gaullist g ment gave him a state funeral.

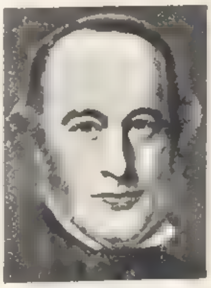
JOULE, JAM ESCOTT (1818–1889)

The ninete century English physicist James Pr tt Joule placed the mechanical theo of heat on a sound experimental b s. He established the principle of the interconvertibility of various forms of nergy. When applied to heat, the principle is known as the first law of thermodynamics. His name was given to a unit of energy, the joule.

In his researches, which were known for their exactness and refinement, Joule found that when heat is generated by the expenditure of mechanical work, or mechanical work is produced at the expense of heat, there is a constant ratio of equivalence between the heat generated and the work expended, and vice versa. The great value of his work in establishing the principle of the conservation of energy lay in the variety of his experimental evidence.

Joule was born at Salford, Lancashire, England. He studied for a time with the chemist and physicist John Dalton but was otherwise self-taught in science. In a long series of experiments, Joule studied the quantitative relationships of electrical, mechanical, and chemical effects.

In 1843 Joule announced his first determination of the mechanical equivalent of heat—the amount of work required to produce a unit of heat. To obtain this data he used four increasingly accurate methods. First he measured the rise in temperature, the current, and the mechanical work resulting from rotation of a small electromagnet in water between the poles of another magnet. In the second method he measured the rise in temperature by forcing water through capillary tubes. The third method depended upon the compression of air, and the fourth produced heat by means of the friction of liquids. Joule adopted as his final value the approximate figure 772 foot-pounds (ft-lb) per British thermal unit (BTU). In other words, he deduced the value 772 for the mechanical equivalent of 1 BTU—the heat required to raise 1 lb of water 1° F. He was not the first to determine the mechanical equivalent of heat, but he was the most accurate up to his time. The value 772 ft-lb was accepted universally for many years but was later adjusted to 778.



James Joule

The physicist William Thomson (later Lord Kelvin) helped arouse interest in Joule's work, collaborating with him during the 1850s. Their observation known as the Joule-Thomson effect shows that when a gas is allowed to expand freely, its temperature drops slightly. This is taken as evidence that in moving apart during expansion, the molecules of gases lose energy and, therefore, temperature in overcoming attraction for their neighboring molecules.

In 1850, a year after his definitive paper "On the Mechanical Equivalent of Heat" was read to the Royal Society of London, Joule was elected to that body and in 1866 received its Copley Medal. He served as president of the British Association for the Advancement of Science in 1872 and in 1887. His *Scientific Papers* were collected and published in two volumes by the Physical Society of London.

JUNG, CARL GUSTAV (1875–1961)

The Swiss psychologist and psychiatrist Carl Jung, an early associate of Sigmund Freud, was the founder of analytic psychology. He classified man into introvert and extrovert types and developed the idea of unconscious collectivism.

Jung was born in Basel, Switzerland, the son of a clergyman. He studied medicine at the University of Basel and then went to Paris to study psychology under Pierre Janet. On his return to Switzerland, he became a physician in the psychiatric clinic of the University of Zürich and a lecturer in psychiatry.

In 1907 Jung met Freud and became a devotee of his theories. He also became a member of the International Psychoanalytic Society, an organization in which Freud was prominent. Their association ended, however, when Jung, dissatisfied with the Freudian stress on infantile sex as the predominant motivation factor in behavior, developed his own theory of the unconscious and the libido and founded a new school in Zürich with an associate, A. Maeder. (*See* Sigmund Freud.)

The new theory set forth by Jung was called analytical psychology rather than psychoanalysis. He classified personalities as introverts or extroverts, further distinctions depending on whether one or more of the four primary mental functions—thinking, feeling, sensation, and intuition—predominates. To discover man's neuroses, he felt that it is more important to study man's immediate troubles than to delve into his behavior as an infant. In defining the libido, he emphasized that man's will to live is stronger than his sexual drive. His idea of the collective unconscious, involving the idea that the human mind contains impressions inherited from ancestors, was revealing of his great interest in mythology and archaeology.

From 1933 to 1941 Jung was a professor of psychology at the Federal Polytechnical Institute in Zürich and in 1943 became professor of medical psychology at the University of Basel. His published works include *Psychology of Dementia Praecox* (1909), *The Theory of Psychoanalysis* (1912), *Psychology of the Unconscious* (1916), *Collected Papers on Analytical Psychology* (1916), *Studies in Word Association* (1918), *Psychological Types* (1923), *Contributions to Analytical Psychology* (1928), *Two Essays on Analytical Psychology* (1928), *Modern Man in Search of a Soul* (1933), *Psychology and Religion* (1938), *Integration of the Personality* (1939), and *Essays on Contemporary Events* (1947).

KAMERLINGH-ONNES, HEIKE
(1853–1926)

One of the pioneers in the area of cryogenics was the Dutch physicist Heike Kamerlingh-Onnes. He succeeded in liquefying helium at an extremely low temperature and went on to investigate the properties of other substances at temperatures near absolute zero. For this work he was awarded the 1913 Nobel Prize in physics.

Kamerlingh-Onnes was inspired by the work of Johannes van der Waals on the gaseous and fluid states of substances. To measure the temperature, pressure, and volume of gases with extreme accuracy, Kamerlingh-Onnes believed that low temperatures were essential, which would necessitate the liquefaction of gases. (*See* Johannes Diderik van der Waals.)

Thus, Kamerlingh-Onnes became interested in the problem of liquefying gases and in 1908 succeeded in producing liquid helium, the only gas that had not yet been liquefied. In the course of his work on liquid helium he attained a new low temperature, within one degree of absolute zero.

He went on to do outstanding work in the field of low-temperature physics. In 1911 he discovered the phenomenon of superconductivity, finding that the electrical resistance of certain metals—such as cadmium, lead, and mercury—almost disappears at temperatures near absolute zero. He also did work on thermodynamics, magneto-optics, and radioactivity. In his laboratory, liquid hydrogen was first produced; and one of his pupils produced the first solid helium.

Kamerlingh-Onnes was born in Groningen, the Netherlands, and entered the university there in 1870. The following year he went to the University of Heidelberg, where he studied with Robert Wilhelm Bunsen and Gustav Robert Kirchhoff. Kamerlingh-Onnes returned to the University of Groningen and wrote his doctoral thesis on studies of new proofs of the rotation of the Earth. He received his doctorate in 1879 and three years later was appointed professor of experimental physics at the University of Leiden, where he founded the famed Cryogenics Laboratory in 1894 and spent the remainder of his academic career.

In 1912 he was awarded the Rumford Medal of Britain's Royal Society and in 1916 was elected a foreign member of the society. He became a foreign associate of the French Academy of Sciences in 1925.

Superfluidity is a property unique to liquid helium, which was first produced in 1908 by the Dutch scientist Heike Kamerlingh-Onnes, known for his work in low-temperature physics. Appearing to deny all physical laws, liquid helium can flow up the sides of its container and into a beaker suspended in the liquid; and when the beaker is lifted above the surface of the liquid, the helium already in the beaker flows up and out of it.

KARMAN, THEODORE VON
(1881–1963)

One of the men res...nsible for the technology that made p...ible supersonic aircraft and guided mis... was the Hungarian-American aero...amicist Theodore von Karman. He ...ed mathematical analysis to problem... aerodynamics and had the ability to ...tute practical applications for the ...ematical formulas he developed

Theodore von Karman

Karman was born a...dapest, Hungary. He was educat... at the Royal Technical University i... lapest and at the University of Gött... in Germany, from which he receiv... doctorate in 1908. Before pursuin... octoral studies, he taught at th... al Technical University and worke... mechanical engineer in Germany

He taught at Götti... rom 1909 to 1912, when he becam... ssor of aeronautics and mechanic... director of the Aeronautics Institu... the University of Aachen in G...any. During World War I he serve... a lieutenant in the Austro-Hungarian ...ation Corps. While serving with the ...ilitary he developed a helicopter with two counter-rotating propellers.

In 1928 he accepted a position as research associate at the California Institute of Technology, Pasadena, but he still held his professorship at Aachen; and in 1930 he became the director of the Guggenheim Aeronautical Laboratory at the institute, a post he held until 1949. From 1942 to 1945 he was also director of its jet-propulsion laboratory and in the former year founded the Aerojet Engineering Corporation later renamed (the Aerojet-General Corporation). His firm began by manufacturing jet-assisted take-off rockets and eventually progressed to the production of guided missiles.

He developed the first theory of supersonic drag, which came to be known as the Karman vortex trail, and also worked out the Karman double-modulus theory of columns and the Karman similarity theory of turbulence. He was an expert on the design of supersonic wind tunnels,

and his initial research on flight phenomena eventually led to the development of the first aircraft to break the sound barrier. His research in mathematical analysis extended to problems in thermodynamics, hydrodynamics, the strength of materials, and vibration phenomena.

During his career Karman served as a consultant to many private corporations and government agencies. In 1944 he became chairman of the U.S. Air Force's Scientific Advisory Board and in 1951 chairman of the Aeronautical Research and Development Group of the North Atlantic Treaty Organization.

He received [illegible] honorary degrees from universities and technical institutes all over the world. In addition, he was elected to membership in many of the world's scientific and professional organizations. In 19[illegible] he was awarded the medal of the American Society of Mechanical Engineers; in 1946, the Medal for Merit; in 1954, the Wright Brothers Memorial Trophy, and in 1955, the David Guggenheim Medal.

KARRER, PAUL (1889–)

The Swiss chemist Paul Karrer was the first to firmly establish the chemical structure of a vitamin. For his work on the constitution of carotenoids, flavins, and vitamins A and B_2, he shared the 1937 Nobel Prize in chemistry with the British organic chemist Sir Walter N. Haworth. (*See* Sir Walter Norman Haworth.)

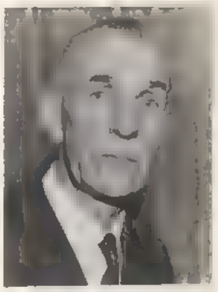
Karrer was born in Russia of Swiss parents, who took him to Switzerland when he was three years old. He was educated at the University of Zürich, receiving his doctorate in 1911. After a year at the Chemical Institute in Zürich he worked six years with the great medical researcher Paul Ehrlich at the Georg Speyer Haus in Frankfurt am Main, Germany. Karrer returned to Zürich as professor of chemistry in 1918 and headed the chemistry department from 1919 to 1959. He became director of the Chemical Institute as well in 1919.

Karrer was instrumental in advancing the study of carotenoids—yellow pigments, such as those in carrots and egg yolk. He isolated new varieties, elucidated the structure of many, and showed that some are changed into vitamin A in the body. With his associates Karrer synthesized vitamin A. He also synthesized vitamin B_2 (riboflavin) in 1935 and vitamin E (tocopherol) in 1938 and confirmed the structure ascribed to vitamin C (ascorbic acid).

A better understanding of the vitamin's part in metabolism resulted from Karrer's research in the 1930s. For his efforts he was elected to many scientific societies and awarded numerous prizes and honorary degrees.

KASTLER, ALFRED (1902–)

For his theoretical atomic investigations the French scientist Alfred Kastler won the 1966 Nobel Prize in physics. He received the award specifically for the discovery of optical means for studying resonance peaks of irradiated atoms. His optical pumping and double-resonance method furthered knowledge of atomic structures and led to the development of both the maser and the laser and a new way of measuring weak magnetic fields.



Alfred Kastler

Kastler was born in Guebwiller, Alsace, Germany, where he went to elementary school. After graduating in 1926 from the École Normale Supérieure in Paris, France, he taught both in Alsace and Bordeaux. He took a doctorate in physics at the University of Bordeaux in 1936 and two years later was made a full professor there. In 1941 he returned to teach at the École Normale Supérieure and at the Faculty of Science of Paris.

KATZ, SIR BERNARD (1911–)

The German-born British biophysicist Sir Bernard Katz shared the 1970 Nobel Prize in physiology or medicine with the U.S. biochemist Julius Axelrod and the Swedish physiologist Ulf von Euler. The award-winning research, done by each independently, was centered on the chemistry of nerve impulse transmission and the chemicals that act as transmitters. (*See* Julius Axelrod; Ulf Svante von Euler.)

Katz, professor at University College, London, was cited for discoveries about the mechanism for releasing acetylcholine, a transmitter chemical substance, from the nerve terminals at the junction of nerve and muscle and under the influence of nerve impulse. He demonstrated the way in which the transmitter is released from nerve endings while the nerve is at rest and while it is sending out impulses. The acetylcholine is released in packets of molecules. More of the groups of molecules are released when the nerve is sending impulses. Clarification of this transmission process opened the way for other scientists to begin studies more directly related to health.

Katz was born in Leipzig, Germany, and earned his medical degree at the university there. After fleeing to London from Nazi Germany, he began his research in nerve and muscle functions. He spent four years in biophysical research at University College, London, before going to Sydney, Australia, in 1939 as a Carnegie Research fellow. For three years during World War II he was a radar officer in the Australian air force. He returned to University College in 1950 as a faculty member.

In 1969 Katz was knighted. He won many professional honors, including membership in the Royal Society, and delivered several guest lectures in the United States.

KEKULÉ VON STRADONITZ, FRIEDRICH AUGUST (1829–1896)

A brilliant theorist, the nineteenth-century German chemist Friedrich Kekulé von Stradonitz laid the foundation of structural organic chemistry. He was remarkable for his ability to visualize the combinations of carbon compounds.

Kekulé was born in Darmstadt, Germany, and educated at the University of Giessen. At first he intended to become an architect but, coming under the influence of the great chemist Justus von Liebig, turned to chemistry. After receiving his doctorate from Giessen in 1852 and studying further in Paris, France, and London, England, he became a lecturer at the University of Heidelberg, Germany, in 1856 and a professor of chemistry at Ghent, Belgium, two years later. In 1865 he moved to Bonn, Germany, where he spent the rest of his life and received the title of nobility that added Von Stradonitz to his name.

Until Kekulé's theories were developed, chemists had represented the atomic composition of molecules by simple formulas of chemical symbols and numbers. In these formulas the numbers show how many of each kind of atom are present; for example, C_2H_6O means that a molecule of this compound contains two carbon atoms, six hydrogen atoms, and one oxygen atom. Some compounds, however, can be more than one kind of substance, depending on their structure; but this is not indicated by this type of formula. Thus, C_2H_6O can be either an

ether or an alcohol, depending on whether the oxygen molecule lies between the two carbon atoms or between two hydrogen atoms—an ether if the former case, and an alcohol if the latter. To show the "layout" of the molecules—that is, what is bonded to what and where—Kekulé therefore devised what are known as structural formulas.

In 1858 he presented his theory that carbon atoms can link directly with one another to make compounds of long chains, which answered the long-standing question of how carbon atoms bond. Organic chemists were then able to start determining the structures of the growing number of organic compounds. The structure of benzene and related ring compounds remained a particular problem, however; and its solution was of great importance to the new field of synthetic dyes. In 1865 Kekulé realized that the benzene molecule consists of a chain that is ring shaped. The great German dye industry of the late nineteenth century was based on this insight and the experimental work that followed.

KELLY, WILLIAM (1811–1888)

The man considered by the U.S. Patent Office to have been the original developer of the air-boiling process for making steel was the U.S. inventor William Kelly. A similar process was invented by the Englishman Henry Bessemer, however, and the converter used in the process was given Bessemer's name. (*See* Sir Henry Bessemer.)

Kelly, the son of a wealthy landowner, was born in Pittsburgh, Pennsylvania. Although he had always been interested in metallurgy, his education did not extend beyond that acquired in the public schools; and by the time he was thirty-five years old, he was a junior partner in a dry-goods business in Philadelphia.

While in Nashville, Tennessee, on a debt-collecting trip for his company, Kelly met his future wife—the daughter of a tobacco merchant—who came from Eddyville, Kentucky. This marked a turning point in Kelly's life. He married, settled in Eddyville, and, with his brother, purchased nearby land containing iron ore.

Using a Cobb furnace, Kelly began making sugar-boiling kettles for the farmers in the area. The manufacture of the kettles entailed converting pig iron to wrought iron by a charcoal-burning process. A great deal of charcoal was needed, however, and when the local supply of charcoal began to run out, Kelly became concerned over his rising production costs.

He began experimenting with ways to cut costs and accidentally discovered that a blast of air on molten iron would burn the excess carbon out of the iron. Furthermore, he found that the carbon in the iron would act as fuel and produce much greater heat. His discovery, however, was not greeted with enthusiasm. When he spoke of making steel without fuel, his wife thought that he had become mentally unbalanced and called in doctors to treat him. Finally his customers' fears that the iron produced by this method was inferior forced Kelly to return to the old charcoal-burning process.

Nevertheless, he did not abandon his experiments. Secretly, in a secluded area of the surrounding forest, be began building experimental converters, constructing seven of them between 1851 and 1856. Then he learned that Bessemer had been granted a U.S. patent on an air-boiling process similar to his own, but Kelly was able to convince the patent officials that he was the original inventor of the process and in 1857 was granted a patent. In 1871 his patent was renewed, but Bessemer's was not. The first steel produced under Kelly's patent was made at the Wyandotte Ironworks near Detroit, Michigan, in 1864.

After his initial success Kelly encountered more misfortune. During the panic of 1857 he was forced to declare bankruptcy, and in dire need of money he sold the newly acquired patent to his father for $1,000. When his father died, the patent was willed to Kelly's sisters, who refused to return it because they felt Kelly was an incompetent businessman. Fortunately, Kelly was invited to carry on his experiments at the Cambria Ironworks (which later became part of the Bethlehem Steel Company) at Johnstown, Pennsylvania. There he constructed his eighth converter, which made possible for the first time the economical production of soft steel.

He finally moved to Louisville, Kentucky, where he established an ax-making company and lived for the remainder of his life. In contrast with the $10 million in royalties and the knighthood accorded to Bessemer, Kelly earned about $450,000 from his invention.

KELVIN, LORD. See Thomson, Sir William.

KENDALL, EDWARD CALVIN
(1886–   )

For his work in isolating the steroid cortisone, the U.S. biochemist Edward Calvin Kendall shared the 1950 Nobel Prize in medicine or physiology with his colleague P. S. Hench and the Swiss chemist Tadeusz Reichstein. Kendall is distinguished also for isolating the active constituent of the thyroid gland. (*See* Philip Showalter Hench, Tadeusz Reichstein.)

Kendall was born at [illegible]uth Norwalk, Connecticut, where his [illegible]er was a dentist. He was educated [illegible]olumbia University, New York City, [illegible]ving his doctorate in 1910. At Sai[illegible]e's Hospital in New York, he be[illegible] investigating the chemistry of the t[illegible]d gland. He completed the project [illegible] the isolation of thyroxin, the thyroid [illegible]one, in 1914, shortly after joining the [illegible]o Clinic staff in Rochester, Minnesota[illegible]om 1915 until his retirement in 195[illegible] headed the Division of Biochemistr[illegible] Mayo Clinic, acting also as head of [illegible] biochemistry laboratory from 1945 u[illegible]951. The following year he became [illegible]ing professor of chemistry at Prin[illegible] University. Meanwhile, in 1950, he [illegible] been elected to the National Academ[illegible] Sciences.

After discovering th[illegible], which became an important t[illegible]eutic agent, Kendall turned his inte[illegible] the adrenal gland. Its inner part [illegible]ulla) manufactures epinephrine, [illegible] already had been isolated; but its [illegible]r part (cortex) manufactures seve[illegible]stances that still were unidentif[illegible]Kendall—and Reichstein, in Switze[illegible]—worked on this problem in the 1[illegible] During that time Kendall isolated [illegible]ast twenty-eight cortical hormone[illegible]h of which was tested on laborat[illegible]nimals. The effective ones he desig[illegible] by a letter. Compound E was one of [illegible]e. Beginning in the late 1940s, under [illegible] name cortisone, it proved to be effective in the treatment of Addison's disease (adrenal cortical insufficiency) and rheumatoid arthritis.

KENDREW, JOHN COWDERY
(1917–   )

John Cowdery Kendrew, British chemist and molecular biologist, was awarded the 1962 Nobel Prize in chemistry for making the first successful determination of the structure of a protein. His co-winner was the Austrian-born British chemist and crystallographer Max F. Perutz. Kendrew worked on the structure of myoglobin, a protein in muscles that stores oxygen and supplies it to the muscle cells when they need it. (*See* Max Ferdinand Perutz.)

Kendrew was born at Compton, Berkshire, England. He was educated at Oxford University; at Clifton College, Bristol; and at Trinity College, Cambridge, where he received his doctorate in 1949.

During World War II, Kendrew was engaged in operational research with the Royal Air Force. After the war he returned to Cambridge and began his collaboration with Perutz. Together they founded in 1947 the Medical Research Council Unit (MRC Laboratory) for Molecular Biology, which has been the site of many milestone discoveries.

The two men sought to learn how the amino acid chains were arranged within the protein molecule. To do so, they had to determine the exact position of each atom. Many proteins form crystals, and the structure of crystals can be determined by x-ray diffraction. X-rays beamed at a crystal form a pattern of spots on a photographic plate behind the crystal, and from the diffraction pattern the structure of the molecule can be deduced. Experimenting with x-ray crystallography, Perutz made a vital discovery in 1953. He showed that attaching a heavy atom, such as mercury or gold, to each molecule of hemoglobin (which was his particular subject of research) alters the x-ray pattern of the crystal so that some spots become stronger and some weaker. He was the first to use this technique in the field of complex molecules. Kendrew and his colleagues then applied the method to their study of myoglobin. Although they solved the protein structure in 1957, the picture was rather blurred. After measuring thousands of additional reflections, they were able in 1959 to draw an accurate three-dimensional picture of the myoglobin molecule.

Kendrew was appointed scientific adviser to the British Ministry of Defense in 1960. That same year he was elected a fellow of the Royal Society.

KEPLER, JOHANNES (1571–1630)

Modern astronomy, which originated between the late sixteenth century and the early seventeenth century, was founded on the work of Nicolaus Copernicus, Tycho Brahe, Galileo, and Johannes Kepler. The basis of astronomy had always been observation, but a rather superficial observation that had led only to the classification of the stars and planets. By measuring the motion of the planets, astronomers had managed to establish empirical laws that served to predict the position of the planets in the sky. No serious attempt had been made, however, to interpret the system of the universe, and the so-called men of learning believed blindly in the views expressed in Ptolemy's writings and did not submit them to the slightest critical examination.

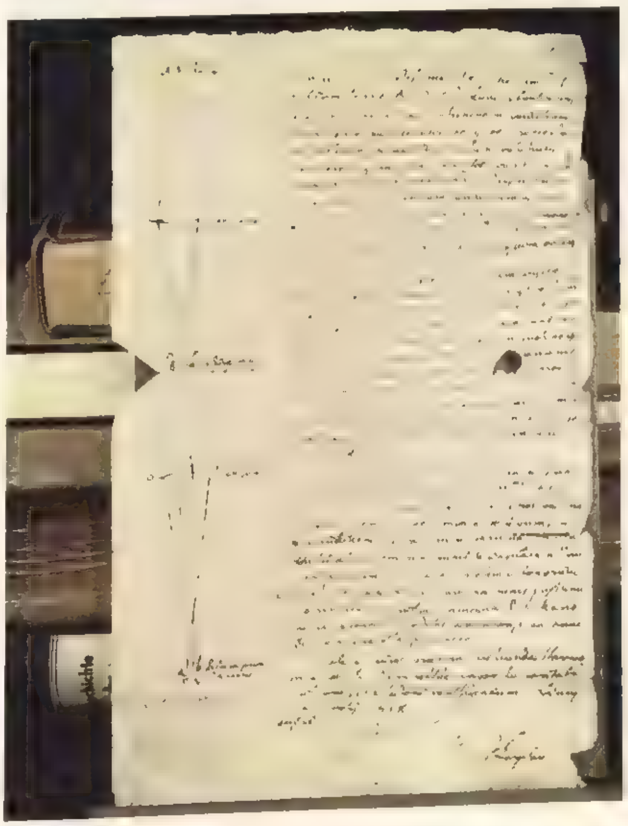
To destroy the Ptolemaic system it was necessary to observe the stars from a point of view that was speculative and not simply descriptive. The great men who confuted Ptolemy had quite different destinies: Copernicus' role was that of precursor, Brahe remained an agnostic collector of observations, and Galileo had to fight to enable the Copernican ideas to prevail. The German astronomer Kepler, on the other hand, seemingly played a subsidiary part, his destiny being to fight against material difficulties rather than against the erroneous ideas and the animosity of his adversaries.

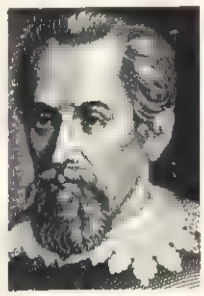
Even from a superficial examination it becomes apparent that the most striking characteristic of Kepler's life, with all its miseries and incomprehensions, its financial hardships and family griefs, was perseverance in his views and faithfulness to his principles. Even his birth seemed ill starred: his father, Heinrich, was a mercenary who had chosen to forget his noble origins and follow his vagabond instincts; his mother, Catherine Guldenmann, also once of a noble family, was a rather ignorant woman who was abandoned four times by her husband and who never appreciated her son's exceptional intelligence. Johannes was born a fragile, premature child at Weil, Württemberg; later, while he was being reared by grandparents, smallpox and scarlet fever crippled his hands and permanently weakened his eyesight.

From force of circumstance Kepler's studies were sporadic. After beginning school in both Weil and nearby Leonberg, he had been obliged to interrupt them in order to help out in his mother's inn. Because of his delicate health, however, he was unfit for the hard tavern work and so entered the convent schools of Adelberg in 1584 and Maulbronn in 1586. Two years later he received a bachelor's degree and entered the University of Tübingen, where he became the favorite pupil of Michael Mästlin, a famous astronomer who had the distinction of giving his name to a large lunar crater. Officially, Mästlin taught astronomy according to the Ptolemaic ideas, but in private he taught and followed the ideas of Copernicus.

Kepler took his master's degree in philosophy in 1591 and wanted to enter the ministry. He was persuaded, however, to begin teaching mathematics and astronomy at a Lutheran school in Graz, Styria, in 1594. He detested astronomy as much as he loved mathematics; yet, with German conscientiousness, once he had been forced for financial reasons to accept the post offered him by the governor, Archduke Karl of Austria, he made it a point of honor to broaden his knowledge of astronomy. He grew so passionately in-

In the course of his work, Johannes Kepler sometimes corresponded with Paul Guldin, a Swiss mathematician and student of solid geometry.





Johannes Kepler

terested in the subject that only two years later he published a work, the *Mysterium cosmographicum*, which, although it contained theories that were to prove erroneous, nonetheless remains valid because of various arguments that are courageously brought forward in support of the Copernican hypothesis. The book amply proved his ability and served to enhance his reputation with other scientists and to put him in correspondence with both Galileo and Tycho Brahe. The former sent him his congratulations, and the latter invited him to join him in Prague, where he was the official court astronomer for Holy Roman Emperor Rudolf II.

Since all Protestant theologians were expelled from Graz shortly after Kepler married Barbara von Mühleck in 1597, he accepted Brahe's invitation and, with his wife, fled to Prague to become his assistant. At first his life in the Bohemian capital cannot have been easy because of his ailing health, Brahe's difficult character, and the whims of the emperor, who was interested chiefly in having horoscopes and predictions from his astronomers and who often forgot to pay them.

Brahe died within a year, but it was from the study of his observations that Kepler drew the material that he used to work out his famous laws on the motion of the planets. Copernicus, whose ideas Kepler followed, had presumed that the planets moved around the sun in circular orbits; this theory was obviously only an approximate one. By examining Brahe's observations, Kepler discovered that the planets' movements are elliptical.

Kepler succeeded Brahe as royal astronomer, and many of his important works date from this productive period. The best of them are *De stella nova* (1605), which contains the description of a temporary star that he had observed for the seventeen months of its visibility, and *Astronomia nova* (1609), which is the fundamental work that states the first two laws of planetary motion that bear Kepler's name (his third law was published in 1619). During the same period Kepler did pioneer work in calculus and also made an active study of optics; it was he who perfected the newly invented telescope through the important modification of the eyepiece. His optical studies were published in *Dioptrice* in 1611.

Meanwhile, his adverse destiny still pursued him. He was afflicted by chronic poverty, which forced him to compromises unworthy of his scientific aspirations; poor health; family misfortunes (he lost his first wife, who went mad, and their three children); and persecution, even in exile, by his own coreligionists, who had him excommunicated for his anti-Ptolemaic and liberal convictions.

In 1612 he was obliged to accept a post in Linz, Austria, in an attempt to obtain a salary from Emperor Matthias, the successor of the inept Rudolf and much less of a patron of science. In 1613 he married Susanna Reutinger, and three years later the news reached them that his mother had been imprisoned on a charge of witchcraft. For at least six years he traveled back and forth between Linz and Württemberg and finally managed to secure his mother's release, though she died shortly thereafter. The disgrace reflected on him as he struggled against his usual poverty (because of his straitened circumstances he even sold a chain given to him by the Grand Duke of Tuscany) and troubles at home (he lost several of the seven children born to his second wife).

When Matthias died, Kepler found himself once more unemployed, at a time when Germany was in the throes of the Thirty Years' War, and in 1626 he moved to Ulm. It was not until 1627 that he succeeded in having the famous Rudolphine, or Tycho Brahe, Tables published. They had entailed exhausting revision work, countless disputes with Brahe's heirs, and finally the laborious search for funds for their printing. They contain logarithm tables and a catalog of 777 stars increased by Kepler to 1,005; and although they are not free of errors, they were used by astronomers for more than a century to calculate the position of the planets.

In Kepler's own complex works, too, which he continued publishing, are combined an exceptional grasp of the laws of nature and a series of extravagant errors, partly conditioned by the beliefs of the time and partly by his theological and Pythagorean hypotheses, factors that were destined both to promote and to impede his research.

In 1628 Kepler moved to Silesia to accept the post of mathematician to the Prince of Sagan, Albrecht von Wallenstein, which was in reality little more than that of soothsayer. Two years later he went to Leipzig, Saxony, and then to Ratisbon, Bavaria, to present a petition to the Diet there. In the course of this long and fruitless journey he fell seriously ill and died far from his family.

KHORANA, HAR GOBIND (1922–)

Har Gobind Khorana

For his part in deciphering the genetic code, the chemist Har Gobind Khorana was one of the three U.S. scientists who shared the 1968 Nobel Prize in medicine or physiology. Khorana, Robert W. Holley, and Marshall W. Nirenberg, working independently, determined how cells transmit genetic messages so that their offspring inherit their composition and functions. Using a method employing synthetic materials, Khorana confirmed Nirenberg's findings that genetic material is composed of four basic substances and that the way the substances are linked in large molecules of DNA (deoxyribonucleic acid) determines the composition and function of a new cell. Holley discovered the manner in which the amino acids are produced by transfer-RNA (ribonucleic acid) within the cells. (*See* Robert William Holley; Marshall Warren Nirenberg.)

In the course of his research Khorana proved that the key combinations come in separate groups of three. He also found that some of the groups prompt a cell to start or stop the manufacturing of protein and that some of the amino acids are precipitated by more than one combination.

Khorana was born in Raipur, India, and earned two chemistry degrees at the University of the Punjab, Lahore, West Pakistan. After receiving a doctorate in 1948 from the University of Liverpool in England, he did additional study at the Federal Institute of Technology in Zürich, Switzerland. He served as head of the Organic Chemistry Group of the British Columbia Research Council before going to the University of Wisconsin and becoming a professor and group leader at its Institute of Enzyme Research in 1960 and the Conrad A. Elvehjem Professor of Life Sciences in 1964.

KIRCHHOFF, GUSTAV ROBERT (1824–1887)

The most impo[illegible] contribution to scientific knowledg[illegible]de by the German physicist Gusta[illegible]chhoff was in the field of spectru[illegible]alysis. Along with Robert Bunsen [illegible]eloped the spectroscope and disc[illegible] the element cesium. He also did out[illegible]g work in theoretical physics, p[illegible]larly in analytical dynamics. (*See* [illegible]t Wilhelm Bunsen.)

Kirchhoff was [illegible] in Königsberg, Prussia, and studied [illegible]he university there. After working a[illegible]rivatdocent at Berlin from 1847 to 1[illegible] was appointed extraordinary pro[illegible] of physics at Breslau. In 1854 h[illegible]came a professor of physics at the [illegible]ersity of Heidelberg and stayed the[illegible]r more than twenty years before r[illegible]g to Berlin in 1875 as professor of [illegible]matical physics.

At Heidelber[illegible]irchhoff began working with Buns[illegible]n photochemical phenomena. Buns[illegible] was studying light produced thro[illegible] colored filters, and Kirchhoff sug[illegible] using a prism. Together they d[illegible]ed the first spectroscope, in whi[illegible]ht passed through a narrow openi[illegible]nd then through a prism. With [illegible]pectroscope, different wavelengths [illegible] were refracted differently and a[illegible]d in different colors. Because each [illegible]nt produced its own pattern of col[illegible]ines, the spectroscope proved usefu[illegible] analytical tool. Using the spectros[illegible] Bunsen and Kirchhoff discovered a [illegible]ement, cesium (1860).

Subsequen[illegible]hile working with incandescent s[illegible] vapor, Kirchhoff discovered that [illegible]spectroscope could be used for anal[illegible]g the chemical composition of celes[illegible]l bodies and formulated the law now known by his name that a gas emitting certain wavelengths when heated will selectively absorb the same wavelengths when cool. By studying the dark lines of the sodium spectrum and those of the solar spectrum, Kirchhoff concluded that sodium exists on the sun.

Kirchhoff's earliest research was done on electrical theory, showing that electric impulses travel at the same velocity as light and developing a theorem giving the distribution of currents in a network. He also did work on the thermal conductivity of iron, crystalline reflection and refraction, the thermodynamics of solution, the theory of vibrating plates, and the theory of light diffraction.

KITASATO, BARON SHIBASABURO (1852–1931)

The Japanese physician and bacteriologist Shibasaburo Kitasato was a discoverer of the germ that causes bubonic plague. He proved the value of antitoxin in preventing disease, did research on the tetanus and diphtheria bacilli, as well as on anthrax and dysentery, and showed how dead cultures can be used in vaccine.

Kitasato was born at Oguni, Kumamoto Prefecture, and was educated at the Kumamoto Medical School and at the Imperial University of Tokyo, graduating in 1883. He did important research with Robert Koch and Emil von Behring in Berlin, Germany, from 1885 to 1891, when he returned to Tokyo and organized his own laboratory. Although it was taken over by the state the following year and became the Imperial Japanese Institute for the Study of Infectious Diseases, Kitasato remained its director for more than twenty years, resigning in 1914 to found the Kitasato Institute. In 1908 he was elected a foreign member of the Royal Society, and in 1924 the emperor made him a baron.

KLEIN, CHRISTIAN FELIX (1849–1925)

The work of the German mathematician Christian Felix Klein had a major influence on the development of modern mathematics. He concentrated on geometry and the theory of functions, and it was mainly in this area of mathematics that he made his greatest contributions.

He began by doing research in geometry and later did work on transformation groups. In the 1870s he presented his *Erlangen Programm*, giving a broad view of the group concept in geometry. Through the efforts of Klein, non-Euclidean geometry came to be accepted as geometry with a particular type of metric. He went on to apply groups theory to other branches of mathematics. He was also interested in the application of mathematics to physics.

Klein was born in Düsseldorf and received his education at Bonn, Göttingen, and Berlin. In 1872 he was appointed professor of mathematics at the University of Erlangen. It was in his inaugural speech at Erlangen that he presented the views contained in the *Erlangen Programm*. He left Erlangen in 1875 and taught for a while at Munich before accepting a professorship at the University of Leipzig in 1880. From 1886 to 1913 he was a professor at the University of Göt-

From 1880 to 1886 Felix Klein was professor of mathematics at the University of Leipzig.

Felix Klein

tingen. After 1872 he was also the editor of the *Mathematische Annalen* of Göttingen. In 1895 he founded the famous *Encyklopädie* of mathematics.

KOCH, ROBERT (1843–1910)

A founder of the science of medical bacteriology, the German physician Robert Koch devised methods in the 1870s that are the basis of all modern techniques for studying bacteria. He isolated the causative bacteria for several diseases, but it was mainly for his discoveries about tuberculosis that he won the 1905 Nobel Prize in physiology or medicine.

Koch was born in Klausthal, near Hanover, Germany. He earned his medical degree at the University of Göttingen in 1866 and proceeded to study for a time with the eminent pathologist Rudolf Virchow. After serving as an army surgeon in the Franco-Prussian War (1870–1871), Koch settled in Wollstein, Posen, as district physician.

In his spare time he began his research on the cause of infectious diseases, starting with anthrax, which was attacking cattle in the area. In 1876 he proved experimentally what C. J. DaVaine, a French physician, had suggested in 1863 —that anthrax is caused by a specific microorganism. From the tissues of infected cattle Koch obtained the anthrax bacillus and injected it into mice, thus reproducing the disease. At the end of his painstaking experiments he recovered the same kind of bacillus. He learned also to cultivate the bacteria outside an organism (in blood serum) and so discovered the life cycle of anthrax bacillus, including the resistant spores.

Koch's reputation grew. In 1880 he was appointed to the Imperial Health Office in Berlin and to the medical school faculty of the University of Berlin, and in 1885 he became professor of hygiene at the university and director of its newly founded Institute of Hygiene. Meanwhile, the Institute for Infectious Diseases was being set up for him in Berlin, and in 1891 he took over its direction. His assistants at the institute included Emil von Behring and Paul Ehrlich, who themselves became Nobel laureates; and students came there from all parts of the world to study the new science of bacteriology.

It was while at Berlin that Koch introduced the modern method of growing cultures in a solid medium, such as agar or gelatin. The use of solid media, in which bacteria cannot move around, is a more efficient way of isolating pure strains of bacteria. It was at Berlin, too, that Koch in 1882 discovered the tuberculosis bacillus and in 1890 announced his preparation of tuberculin. This announcement raised hopes that a cure for tuberculosis was at hand, but tuberculin proved to be a valuable aid in the diagnosis of the disease and nothing more.

Koch also traveled extensively in search of microbes. These travels took him to the far corners of the Earth and must have helped fulfill his youth[illegible] dream of becoming an explorer. Th[illegible]gh his studies of cholera and plag[illegible] India, cattle rinderpest and sleepin[illegible]kness in Africa, and malaria in Italy, [illegible]arned that the plague is transmitted [illegible] flea that infests rodents and tha[illegible]setse fly transmits sleeping sickne[illegible]

For isolating the ch[illegible] bacillus, Koch was awarded the eq[illegible]ut of $25,000 by the German gove[illegible]t. In 1897 the Royal Society of L[illegible] honored him with foreign membe[illegible] in recognition of all his contributio[illegible] the science of bacteriology.

Basic training in m[illegible]n bacteriology includes what are kno[illegible] Koch's postulates: a specific orga[illegible] must be seen in all cases of an infe[illegible]s disease; this organism must be ob[illegible]d in pure culture; organisms from [illegible] cultures must reproduce the disea[illegible] experimental animals; the organis[illegible]t be recoverable from these anim[illegible] G. J. Henle, one of Koch's teacher[illegible]öttingen, first stated these principle[illegible]40, and Koch's discoveries gave the[illegible]rimental confirmation.

KOCHER, EMIL THEO[illegible] (1841–1917)

A Swiss surgeon, E[illegible]eodor Kocher, won the 1909 Nobel [illegible]n physiology or medicine for his w[illegible] the physiology, pathology, and s[illegible] of the thyroid gland. He practic[illegible]liminated the danger in an extreme[illegible]ficult surgical procedure.

Kocher, the son of [illegible]ngineer, was born at Bern. He rece[illegible]d his medical degree from the universit[illegible] there and went on to study in Berlin, London, Paris, and Vienna. In 1872 he became professor of clinical surgery at the University of Bern. As head of its surgical clinic for forty-five years, he influenced many students and assistants.

After attending the International Congress of Medicine in London in 1881, Kocher became a strong advocate of Listerism. The English surgeon Joseph Lister had opened the modern era of surgery with his attempt to provide a germ-free atmosphere in operating rooms by spraying with an aqueous solution of phenol. Its irritating properties, however, soon led to its replacement by asepsis—scrupulous cleanliness achieved with sterilization by heat—and with his characteristic readiness to accept advanced procedures Kocher later adopted this method.

In 1882 Robert Koch discovered the tuberculosis bacilli, which are seen under the microscope as thin rods, often grouped into bundles or joined in short chains.

Robert Koch

Kocher had perform… about 5,000 operations for goiter by … 2. His studies of the thyroid gland arose from these operations for disorder causing enlargement of the gland. As early as 1883 he announced that comp… removal of the thyroid gland leads … characteristic disease pattern but … leaving a portion of the gland to … causes modification of the patter… work was instrumental in coor… ing studies on thyroid malfunction … he stimulated research that led t… introduction of the drugs thyroid a… roxin for treating thyroid disorde…

Kocher's contrib… to surgery included a method f… ducing dislocations of the should… d new or modified techniques for … ry of the lungs, ovaries, stomach, … ladder, tongue, and cranial nerve… ong the instruments and techni… at he devised, the forceps and i… that bear his name are still in … is *Textbook of Operative Surger*… translated into many languages.

KÖPPEN, WLADIM… ER (1846–1940)

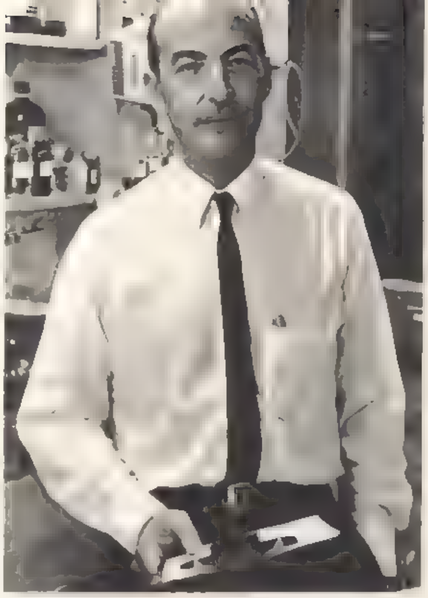
The German … logist Wladimir Peter Köppen is b… wn for his classification of clima… more than forty years his base wa… reat port city of Hamburg, Germa…

Born of Germa… stry in Saint Petersburg (Lenin… Russia, he was educated at the … sities of Heidelberg and Leipzig … rmany. In 1875, after a brief peri… employment with the Russian met… gical service, he became chief of … w division of the marine observato… Hamburg. In that post he was charg… with the initiation of weather foreca… ng for northwestern Germany and the adjacent seas. He remained with the observatory for more than forty years, but after 1879 he was also able to devote himself to fundamental scientific work.

Köppen made studies of the weather and climate of the oceans, investigated the upper air by using kites and sounding balloons, and developed a widely used classification of climates. The major climate categories of this classification were tropical rainy, temperate rainy, snow forest, tundra, and perpetual frost. He also studied the relationship of sunspots to rainfall but reached no conclusions.

KORNBERG, ARTHUR (1918–)

The U.S. physician and biochemist Arthur Kornberg received the 1959 Nobel Prize in medicine or physiology for discovering the mechanism of the biosynthesis of deoxyribonucleic acid (DNA). He shared the prize with Spanish-U.S. physician Severo Ochoa, who earlier had made the same discovery for ribonucleic acid (RNA). (*See* Severo Ochoa.)



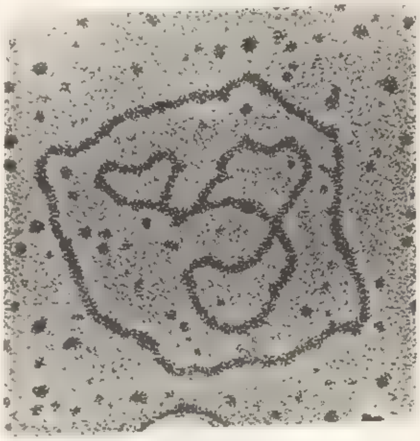
Arthur Kornberg

DNA transmits the genetic information that determines heredity. Kornberg showed how chains of DNA are built up in the cell, opening up new possibilities for understanding genetics. His and Ochoa's work were fundamental also to the study of cell differentiation and of viruses.

An important element of Kornberg's research was the discovery of enzymes that make possible the synthesis of DNA. It was in 1956 that he found an enzyme that, in combination with several nucleotides, would form a synthetic DNA molecule.

Kornberg was born in Brooklyn, New York. He received his bachelor's degree from the City College of the City of New York in 1937 and his doctorate in medicine from the University of Rochester in 1941. After serving his internship at Strong Memorial Hospital in Rochester, he began biochemical research at the National Institutes of Health in Maryland in 1942, where he stayed until 1953, though with several interruptions—during World War II he served as a medical officer in the Coast Guard, in 1946 he worked under Ochoa at New York University, and in 1951 he worked at the University of California at Berkeley. Meanwhile, from 1947 to 1953, he was also head of the enzyme and metabolic section of the institutes. In the latter year he became a professor and head of the microbiology department at Washington University, Saint Louis, Missouri, and in 1959 he became chairman of the biochemistry department of the School of Medicine of Stanford University, Palo Alto, California.

Double viral DNA rings were successfully synthesized in a test tube by Arthur Kornberg and his colleagues at Stanford University, Palo Alto, California, in 1967.



KOSSEL, ALBRECHT (1853–1927)

The German biochemist Albrecht Kossel won the 1910 Nobel Prize in physiology or medicine for his clarification of cell chemistry. His research was concerned mainly with nucleic acids, compounds instrumental in controlling the formation of proteins in the cells.

Kossel was born at Rostock, Germany, and educated there and at the University of Strasbourg. After earning his medical degree in 1878, he engaged in research at the Physiological Institute in Berlin and began an investigation of nuclein, a vaguely defined cell substance that had been isolated a decade earlier. He showed that nuclein contains a protein portion and a nonprotein portion, or nucleic acid. This acid was different from any natural product known before. Purines and pyrimidines were found to be among its breakdown products, and Kossel isolated two purines—adenine and guanine—and three different pyrimidines —thymine, cytosine, and uracil.

In 1895 Kossel became professor of physiology and director of the Physiological Institute at Marburg, Germany, and in 1901 he accepted the corresponding post at the University of Heidelberg, retiring in 1924 as professor emeritus. He maintained his interest in proteins and at the time of his death was director of the Heidelberg Institute for Protein Investigation. For more than thirty years he was also editor of the *Zeitschrift für physiologisches Chemie* (*Periodical for Physiological Chemistry*).

Kossel was a pioneer in the application of the exact methods of organic chemistry. In some ways his analytical work on the chemistry of natural products com-

plemented the work on synthetic products by the 1902 Nobel laureate Emil Fischer, who helped lay the groundwork for research into protein structure.

KREBS, SIR HANS ADOLF (1900–)

The German-British biochemist Sir Hans Adolf Krebs won the 1953 Nobel Prize in medicine or physiology for his discovery of the citric acid cycle in the metabolism of carbohydrates, fats, and proteins. He shared the prize with F. A. Lipmann, who discovered coenzyme A. (*See* Fritz Albert Lipmann.)

The citric acid cycle, or Krebs cycle, is the chief source of metabolic energy. There are many stages in the oxidation of food for energy in the body, and the citric acid cycle is the last stage. Basically it is a series of chemical changes that take place in nine steps. The cycle is common to many types of cells, from the higher animals to lower life forms like mold. In higher animals the cycle provides two-thirds of the energy from food; the other third is set free in the earlier stages of oxidation.

Sir Hans performed his experiments with pigeon breast muscle and pigeon livers. He repeated his tests, however, on other animal life to show the universal applicability of the cycle and in 1937 officially announced discovery of the cycle.

The field of biochemistry was greatly advanced by the work of Krebs and Lipmann. Prime importance must be attached to their studies of intermediary metabolism—that is, the pattern of detailed chemical reactions that are responsible for forming, converting, or breaking down body substances. Very often in the history of biochemistry, scientists had started with a given material and produced another material without being able to explain how or why. Another achievement in Krebs's career was the discovery of the urea cycle in 1932. This cycle involves certain changes in the molecule of arginine, an amino acid.

Krebs was born in Hildesheim, Germany, and studied medicine at the universities of Göttingen, Freiburg, Munich, and Berlin. He completed his studies at Hamburg University and received his medical degree in 1925. From 1926 to 1930 he worked as an assistant to the renowned biochemist Otto Heinrich Warburg and then devoted himself to clinical work in a hospital. In 1933, however, he was forced to leave the institution by the Nazi regime and emigrated to England, becoming a research student at Cambridge. In 1935 he became a lecturer at Sheffield University and in 1945 was promoted to professor of biochemistry. Meanwhile, during World War II, he had performed experiments on vitamin deficiencies. He was appointed director of the Medical Research Council unit for research in cell metabolism in 1954 and that same year was named Whitley Professor of Biochemistry at Oxford University. He was elected a fellow of the Royal Society in 1947 and was knighted in 1958.

KROGH, SCHACK AUGUST STEENBERG (1874–1949)

The Danish physiologist August S. Krogh won the 1920 Nobel Prize in medicine or physiology for his discovery of how the capillaries—the body's smallest blood vessels—regulate the flow of blood to muscles in the body. He found that the number of open capillaries is closely related to tissue activity; that is, the number of open vessels is greater in active muscle than in resting muscle.

Before Krogh, scientists mistakenly believed that contractions of the capillaries were dependent on contractions in the arterioles. Krogh set out to prove that capillaries have an independent contracting mechanism. Using a microscope, he began by observing superficial capillaries in the frog and in various mammals. When he stimulated the muscles of the animals, he saw that a large number of capillaries became dilated and visible. To study the capillaries throughout the body, he injected an India ink solution isotonic with blood into the circulatory system and killed the animals by stopping their circulation. This allowed him to observe which capillaries were open and which were closed at the time of death. The muscles that he had stimulated before death were dark with ink, showing that more capillaries were open where they were needed to carry increased oxygen to the tissues.

Knowledge of the capillaries is very important in the field of medicine. Doctors need to know in detail the functioning of the capillaries to study or treat blood-pressure problems. The condition of shock involves changes in the capillaries, and some allergic reactions depend on changes in the capillaries.

Krogh was born in Grenaa, Denmark. Beginning in 1897, he conducted research in the physiology laboratory of Christian Bohr. He received a master's degree in zoology from the University of Copenhagen in 1899 and a doctorate in 1903 with his thesis on respiration in frogs. Meanwhile, in 1902, he had gone on an expedition to Greenland to study Arctic animals. In 1908 at Copenhagen he became an associate in animal physiology and in 1916 a professor. In his research on the pressures of oxygen and carbon dioxide in the blood, he was assisted by his wife, Marie, who held a medical degree.

Krogh's treatise *M[illegible]anism of Gas Exchange in Lungs* wa[illegible]rded a prize in 1906 by the Vienna [illegible]my of Science. Another of his publi[illegible] was *The Respiratory Exchange [illegible]imals and Man* (1916). In 1922 the S[illegible]an Lectures that he had delivered at [illegible]niversity when he visited the Uni[illegible]tes were published as *The Ana[illegible]nd Physiology of Capillaries.*

KUHN, RICHARD ([illegible]–1967)

For his research o[illegible]mins and carotenoids—the fat-solu[illegible]ellow coloring materials that are w[illegible] spread through nature—the Austrian [illegible] German biochemist Richard Ku[illegible]as awarded the 1938 Nobel Prize in [illegible]istry. His studies of complex organ[illegible]pounds helped solve many medical [illegible]biological problems.

Richard Kuhn

Kuhn was born in [illegible]a and received his doctorate in 1922 f[illegible] the University of Munich, whereupon he was assistant to the German organic chemist and Nobel laureate Richard Willstatter. In 1926 Kuhn became a professor at the Swiss Technical High School in Zürich, where he remained until he was appointed director of the chemistry department of the Kaiser Wilhelm (later Max Planck) Institute for Medical Research in Heidelberg in 1929. He was a professor at the University of Heidelberg for many years and was also associated with the Max Planck Society for the Advancement of Science at Göttingen.

In his investigation of the chemical nature of carotenoids Kuhn discovered at least eight carotenoids, prepared them in pure form, and analyzed their composition. He determined the makeup of vitamin B_2 in 1935, simultaneously with the Swiss chemist Paul Karrer and his associates. In 1937 Kuhn synthesized vitamin A and in 1939 vitamin B_6. (*See* Paul Karrer.)

Kuhn was awa led the Nobel Prize in chemistry a year fter Karrer; but in 1937 Adolf Hitler had ecreed that no German could accep Nobel Prize because the 1935 Nobel eace Prize had been awarded to a p ist who was interned in a Nazi c tration camp, After World War II vever, Kuhn received his prize. He so the recipient of the Pasteur, Pater d Goethe prizes.

KUSCH, POLY (1911–)

The U.S. ph st Polykarp Kusch won the 1955 Nob rize in physics for his discovery of t omalous electron spin moment. He d the prize with the U.S. physicist E. Lamb, Jr. (*See* Willis Eugene La , Jr.)

In 1925 S. Goudsmit and G. E. Uhlenbeck f lated a postulate that quickly bec mainstay of modern physics, deal ith the intrinsic angular momentu the electron. In 1947, however, J. E afe, E. B. Nelson, and I. I. Rabi unc red a discrepancy in the observed and calculated spin moment of the electro usch set himself the task of resolving problem and succeeded in 1949 by ding molecular beams through a n tized vacuum.

Kusch wa n in Blankenburg, Germany, the s a Protestant clergyman, but was tak the United States at age one, becom a naturalized citizen in 1922. He re d his bachelor's degree from the C Institute of Technology, Cleveland, o, in 1931; his master's from the U ersity of Illinois in 1933; and his do ate from Illinois in 1936 for research optical spectroscopy.

For a year after receiving his doctorate he worked as a research assistant in the field of mass spectroscopy at the University of Minnesota. In 1937 he went to Columbia University to work in conjunction with I. I. Rabi on experiments dealing with radio frequency atomic beams. Next, from 1941 to 1942, he was engaged in research on high frequency generators for the Westinghouse Corporation. He was research associate at the Columbia radiation laboratory from 1942 to 1944. He next went to do research at the Bell Telephone Laboratories from 1944 to 1946. From there he returned to Columbia as an associate professor of physics; he was promoted to professor in 1949 and served as chairman of the physics department from 1949 to 1952 and again from 1960 to 1963.

He was elected a member of the National Academy of Sciences in 1956 and was named a fellow of the Center for Advanced Study in the Behavorial Sciences for 1963–1964, as well as of the American Physics Society. He received honorary degrees from Ohio State University, Gustavus Adolphus College in Minnesota, and his alma mater Case Institute.

LAGRANGE, JOSEPH LOUIS
(1736–1813)

The great French-Italian mathematician Joseph Lagrange, who made important contributions to the theory of numbers and to celestial mechanics, was born in Turin, Italy, the only one of the eleven children of a French cavalry officer and his Italian wife to survive infancy. He was educated at Turin College and showed an early interest in the classics. On reading an essay on calculus by the astronomer Edmund Halley, however, he became interested in mathematics and was appointed professor of geometry at an artillery academy when he was only in his teens, though he never had a deep or abiding interest in geometry.

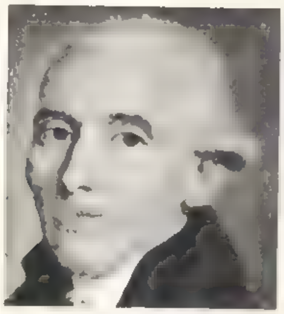
At the age of nineteen he began to send papers on mathematical problems to the eminent German mathematician Leonhard Euler. The method that Lagrange suggested for attacking isoperimetrical problems was recognized by Euler as being similar to his own solution of such problems, but he allowed the young Lagrange to publish his paper first.

In 1758 Lagrange was one of the founders of a group that later became the Turin Academy of Sciences. He contributed many papers to the academy's memoirs, *Miscellanea Taurinensia,* including one on maxima and minima. He also wrote on differential calculus as it applied to the theory of probability.

When he was still in his twenties, he was recognized as one of the greatest living mathematicians. Men had long wondered why the moon always presents essentially the same face to the Earth, and in 1764 Lagrange received the prize of the Paris Academy of Sciences for his essay on the libration of the moon. He also won the academy's prizes for 1766, 1772, 1774, and 1778, several of them for his theory of the system of Jupiter.

Inspired by an essay on calculus by the astronomer Edmund Halley, Joseph Lagrange pursued the study of mathematics with such effect that when he was yet in his teens, he was appointed professor of geometry at the Royal Artillery School of Turin.

When Euler left Berlin in 1766, he recommended that Lagrange replace him at the academy there. Acting on this recommendation, Frederick the Great invited Lagrange to Berlin, calling him "the greatest mathematician in Europe." Lagrange lived in Berlin for twenty years, producing his great work *Analytical Mechanics*, which was not published until 1788 in Paris. In this work he systematized mechanics with general equations, avoiding geometry or diagrams.



Joseph Lagrange

Finding his position in Berlin weakened after the death of Frederick, Lagrange accepted an invitation from Louis XVI in 1787 to live in Paris and was given an apartment in the Louvre. He remained there during the French Revolution, safe from reprisals. In 1793 he became president of the Commission on Weights and Measures, which introduced the metric system to France. For a few months he served as a professor in the École Normale, but the school closed abruptly; and in 1797 he became a professor at the new École Polytechnique. That same year he published *Theory of Analytical Functions*, dealing with differential calculus. He was made a count and a high-ranking official in the Legion of Honor by his great admirer Napoleon.

LAMARCK, JEAN BAPTISTE PIERRE ANTOINE DE MONET, CHEVALIER DE
(1744–1828)

In eighteenth-century France, on the eve of the Revolution, the idea of evolution was practically unknown. Even Jean Baptiste Lamarck, the great French naturalist, reached the age of fifty without having conceived of the theory that, before long, he was to champion.

Lamarck was born at Bazentin, France, the youngest of eleven children. After the violent death of several of his brothers, it was decided that he should become a priest; and, much against his will, he had to leave for a Jesuit college in Amiens. This was not the life to which the young boy had aspired, however; and at the age of sixteen, when his father died, he immediately abandoned the college and enlisted in the Duke de Broglie's army, which was involved in the Seven Years' War in Germany. He fought with such cool-headed courage that he won promotion in the field. A promising career lay ahead of him; but it was suddenly interrupted by a joke played on him by a companion-in-arms, which caused him to fracture his leg and thereby led to his discharge.

In 1765 young Lamarck was therefore faced with the difficulty of finding a new occupation. He dreamed of becoming a doctor; and to get enough money to study at a university, he took a job in a Paris bank. In 1770, partly with his savings and partly with the help of one of his brothers, he was able to enroll in the Paris Faculty of Medicine, where he subsequently obtained his degree. These studies, however, interested him little.

A meeting with Jean Jacques Rousseau had a determining influence on him: the philosopher, who became his friend, persuaded him to take up botany. In 1778 Lamarck published *Flore française*, which earned him little money but many friends, a certain fame, nomination to the Academy of Sciences, and an assignment from the naturalist Georges Buffon to accompany his son on an educational journey. Thus, in 1781–1782, Lamarck traveled through Germany, Italy, and the Low Countries; and even though he seemingly failed to inspire in young Buffon a love of science, he collected new materials and valuable information for himself.

The following deca[illegible] Lamarck went through a difficult perio[illegible] chiefly because of the financial straits [illegible] which he found himself. Finally in 17[illegible] and though he was a botanist, he m[illegible] to obtain the chair of invertebrate [illegible]gy at the National Museum of N[illegible] History, Paris.

While tackling th[illegible] field, Lamarck was working on an [illegible] that had been suggested to him par[illegible] his own conclusions, drawn from [illegible]vation and the direct study of nat[illegible] and partly by theories that he had [illegible] in schematic form in the writings [illegible] her naturalists: theories concerning th[illegible] olution of living creatures. The sci[illegible] ts of the time had not even vaguel[illegible] agined that, in prehistoric ages, spec[illegible] ght have been different from what th[illegible] ere at present; the notion of evolut[illegible] d simply not occurred to them. A[illegible] om this difficulty, there were also [illegible] ms of a practical nature resulting [illegible] arl Linnaeus' monumental work, w[illegible] was still considered absolutely [illegible] tive. Species were, in fact, thoug[illegible] be fixed and immutable. It was i[illegible] lying without wings, because the pr[illegible] s for any evolutionary theory wer[illegible] letely lacking. Since it was not kno[illegible] w hereditary characteristics are tra[illegible] red, it was dif-

Jean Baptiste Lamarck's *Flore francaise* stressed the opposing characteristics of species to help in their ide[illegible] tion and led to his election to the Aca[illegible] Sciences.

Jean Baptiste Lamarck

ficult to talk ab[illegible] mutations and evolution.

Lamarck wa[illegible] ıck by the undoubted existence of ad[illegible] tion in living beings. In the past, La[illegible] k believed, certain environmental co[illegible] tions existed to which living creatur[illegible] dapted. Subsequently, when a differen[illegible] vironment developed, there appeare[illegible] w creatures that were adapted to it [illegible] led Lamarck to the conclusion th[illegible] he environment must have created [illegible] organs and determined the form of li[illegible] g creatures through its active influen[illegible] in other words, by encouraging the [illegible] ans to assume the most suitable form [illegible] eloping some and atrophying other[illegible] day this is known to be erroneous, as [illegible] idea of the inheritance of acquired [illegible] acteristics. In spite of their incorr[illegible] ss, Lamarck's theories were unden[illegible] an important point of departure be[illegible] se they encouraged the scientists wh[illegible] ame after him to undertake a thoro[illegible] investigation of the real cause of ev[illegible] ion.

The basic merit of Lamarck's work was that it upheld the transformism of living species. This merit can be more easily acknowledged today because the inadequacy of the biological knowledge of those times can be fully appreciated. This inadequacy, however, hampered his whole work and frequently led to false conclusions.

His work was not confined to biology, however, but extended into the collateral sciences, where, in truth, his ideas were not only lacking in originality but often were so completely wrong that they jeopardized his reputation. While bringing new ideas to the study of invertebrates at the university, he was also publishing papers in physics and chemistry. Lamarck was a firm believer in the phlogiston theory and opposed Antoine Lavoisier's new chemical theories. Between 1800 and 1810 he published a series of meteorological yearbooks and almanacs full of the most erroneous predictions. This prejudiced his scientific reputation and also reflected on the theory that he was expounding in his lectures at the museum and that he presented in full in his chief work, *La philosophie zoologique* (1809). The book was received with an indifference and hostility that further embittered his old age, which was already afflicted by poverty, misfortunes, and blindness. He had married several times and each time was left a widower. He had lost three of his six children; and only one, his eldest daughter, Cornelia, kept him company in his last years, when, in spite of his blindness, he continued his work on the *Histoire naturelle des animaux sans vertèbres.*

LAMB, WILLIS EUGENE, JR.
(1913–)

The U.S. physicist Willis Eugene Lamb, Jr., won the 1955 Nobel Prize in physics for his research in atomic measurements, which led to new breakthroughs in understanding the effect of the electron in its own magnetic field. He shared the prize with U.S. physicist Polykarp Kusch. (*See* Polykarp Kusch.)

In 1947 Lamb designed an atomic-beam apparatus to measure energy shifts. With this apparatus he and his student Robert Retherford performed resonance experiments involving hydrogen atoms and were able to measure exactly the amount of energy necessary to shift an electron between two very nearly equal energy states. This phenomenon became known as the Lamb shift.

The range of Lamb's work was very broad, including research on lasers and masers, theoretical physics, atomic structure, microwave spectroscopy, and beta decay. He was also the chief author of a series of papers in the *Physical Review* dealing with the fine structure of the hydrogen atom.

Lamb was born in Los Angeles, California, the son of an engineer, and educated at the University of California at Berkeley. After receiving his bachelor's degree in chemistry in 1934 and his doctorate in physics in 1938, he became an instructor in physics at Columbia University, New York City, being promoted to professor in 1948. He was also associated with its radiation laboratory from 1943 to 1951. Following the years 1951–1956, when he was a professor of physics at Stanford University, Palo, Alto, California, as well as the Morris Loeb Lecturer at Harvard University for a year, he went to England to become a fellow of New College and Wykeham Professor of Physics at Oxford University. In 1962, after six years there, he left to become the Henry Ford II Professor of Physics at Yale University.

His professional affiliations included membership in the American Physics Society, the New York Academy of Sciences, and the National Academy of Sciences. He was awarded the Rumford Premium of the American Academy of Arts and Sciences in 1953 and the Yeshiva Award in 1962.

LANDAU, LEV DAVIDOVICH
(1908–1968)

The Soviet theoretical physicist Lev Davidovich Landau received the 1962 Nobel Prize in physics for his studies of liquid helium and of condensed matter. He was particularly known for his explanation of superfluidity in helium II, which is helium cooled to at least 2.2° K (2.2° above absolute zero). Regular liquid helium, or helium I, does not exhibit the superfluid quality. Peter L. Kapitza, director of the Institute for Physical Problems in Moscow, observed that helium II will flow through slits too small for helium I. After analyzing the superfluid quality in terms of quantum mechanics, Landau provided the explanation for the paradoxical flow in terms of a countercurrent and predicted the existence of a new type of wave motion called second sound, which was later experimentally verified to be a type of heat wave and was used to study the properties of helium II in great detail.

One of the characteristics of superfluid helium is the fountain effect. When heat acts on a bulb below the liquid helium level in a reservoir, the helium sprays from the capillary.

Before his work on liquid helium Landau had advanced man's understanding of the properties of metals by examining the behavior of free electrons placed in a magnetic field and giving a detailed mathematical explanation of ferromagnetism, or the magnetic fields produced by the atoms of iron. Later he studied a rare isotope of helium with the atomic weight 3; this type of isotope exists at such low temperatures that it had been extremely difficult to observe or study. He then found another new type of wave motion, called zero sound.

Lev Landau

Landau was born in Baku, Azerbaijan, in the Russian Transcaucasia. His father was an engineer, and his mother a physician. He entered Baku University at the age of fourteen and finished his studies at Leningrad University when he was but nineteen. From 1929 through 1931 he studied abroad, in Denmark, England, Germany, and Switzerland, being particularly fortunate to study under the great physicist Niels Bohr at the Institute of Theoretical Physics in Copenhagen, Denmark. He was head of the theoretical department of the Ukrainian Physical and Technical Institute in Kharkov from 1932 to 1937, when he became head of the theoretical section of the Institute for Physical Problems of the U.S.S.R. Academy of Sciences, located in Moscow.

He was a member of the U.S.S.R., U.S., Danish, and Dutch academies of science, as well as of the Royal Society of London. The Stalin Prize was awarded to him on three occasions.

With E. M. Lifshitz he was the coauthor of a series of physics textbooks. Most of his important papers were collected and published as *Selected Scientific Papers* in 1964.

LANDSTEINER, KARL (1868–1943)

The 1930 Nobel Prize in physiology or medicine was awarded to Karl Landsteiner, an Austrian-born U.S. scientist, for his discovery of the four primary blood groups in humans. The subsequent blood-typing eliminated much of the danger in blood transfusions. This achievement had such important applications that it sometimes overshadows the fact that Landsteiner was the first to isolate the poliomyelitis virus.

By the end of the nineteenth century many countries had prohibited blood transfusions because they so often hastened the patient's death. The discovery in 1901 that human blood differs in the capacity of the serum to agglutinate red cells—that is, to cause them to clump together—was made by Landsteiner. He and his associates divided human blood into four groups according to the different antigens and antibodies in the red cells and serum. In 1909 Landsteiner devised the classification that has been in use ever since—types A, B, AB, and O. By blood-typing the patient and the donor before a transfusion, it can be ascertained that incoming red cells will not be agglutinated, thus eliminating the possibility of fatal results.

In 1927 Landsteiner and his colleagues discovered subgroups that were not important in connection with blood transfusions but that shed new light in anthropological studies. Landsteiner was also involved in the discovery of the rhesus (Rh) factor in the red cells of certain individuals. This breakthrough, announced in 1940, led to ways of preventing miscarriages and deaths of babies who have Rh negative mothers and Rh positive fathers.

Although Landsteiner's main areas of interest were immunology, bacteriology, and pathology, he also did research in virus diseases, as in the instance of poliomyelitis. He isolated the virus in 1908 and introduced it experimentally into monkeys.

Landsteiner was born in Vienna and received his medical degree in 1891 from its university. In 1909 he returned there to teach pathology, staying until he moved to the Netherlands in 1919. Three years later he accepted an invitation to become a member of the Rockefeller Institute for Medical Research in New York City, from which he retired in 1939. In addition to the Nobel Prize, he was also the recipient of the Paul Ehrlich Medal and the Dutch Red Cross Medal.

LANGMUIR, IRVING (1881–1957)

The U.S. physical chemist Irving Langmuir made several major discoveries that had far-reaching applications in everyday life. His research led to the development of the gas-filled tungsten light bulb, the mercury condensation vacuum pump, the

Irving Langmuir

high-vacuum tube that became important in the broadcasting industry, and the atomic-hydrogen welding torch. He also developed an atomic theory, and for his great discoveries in the field of surface chemistry he was awarded the 1932 Nobel Prize in chemistry.

Langmuir was born in Brooklyn, New York, and received his early education in the United States and in Paris. In 1903 he graduated from Columbia University with a degree in metallurgical engineering, and in 1906 he was awarded a doctorate in chemistry from the University of Göttingen, Germany. He taught at the Stevens Institute of Technology, Hoboken, New Jersey, from 1906 to 1909, when he went to work in the research laboratory of the General Electric Company in Schenectady, New York. He became director of the research laboratory in 1932 and stayed with General Electric until his retirement in 1950. During World War I he worked on the development of a submarine detection device, and during World War II he did research directed toward the improvement of smoke screens.

One of his first assignments at General Electric was to develop a light bulb that would last longer than those in existence at the time. Working with the newly developed tungsten filaments, he found that the tungsten atoms evaporated in the vacuum of the bulb when heated and that filling the bulb with a gas that did not react with tungsten retarded the evaporation rate. At first nitrogen was used, and later, argon.

By investigating the discharge of electricity into gases at low pressure, Langmuir discovered the space-charge effect. This, together with his interest in vacuums, led to his development of the mercury condensation vacuum pump and a method for creating high-vacuum tubes later valuable in radio and television.

His study of hot metal surfaces and their effect on gases resulted in his invention of the atomic-hydrogen blowpipe for welding, capable of producing temperatures almost as hot as the sun's surface.

Passing hydrogen gas over hot tungsten wires broke the hydrogen molecules down into atoms; and when the atoms reunited to form molecul[illegible] again, fantastic heat was produced.

In his researc[illegible] on surface chemistry Langmuir studie[illegible] monomolecular layers (films only one [illegible]lecule thick) on the surface of tu[illegible] and platinum filaments and on [illegible]rface of water. From these investiga[illegible] he formulated a theory of adsorp[illegible] which had a major impact on th[illegible] of biochemistry and colloidal che[illegible] and contributed to the knowledg[illegible] how to cut the glare of glass surfac[illegible]

Langmuir al[illegible] worked out an atomic theory to expl[illegible] electron bonding. Although it was [illegible]mulated independently of the U.S. che[illegible] Gilbert Newton Lewis, it came to be k[illegible]wn as the Lewis-Langmuir atomic t[illegible]ry. Langmuir was the first scientist [illegible]se the words *electrovalence* and [illegible]*alence* in describing types of bond[illegible] One of his last undertakings was t[illegible] production of artificial rain. He and [illegible] colleagues devised the method of se[illegible] cumulus clouds with carbon dioxid[illegible] silver iodide to form ice crystals.

LAPLACE, PIE[illegible] SIMON DE
(1749–1827)

The French [illegible]thematician and astronomer Pierre S[illegible]n de Laplace is valued especially fo[illegible] studies of gravitation. His work ela[illegible]ated on that of the brilliant Sir Isaa[illegible] Newton, and he is often called the Ne[illegible]on of France.

Laplace was born in Beaumont-en-Auge, France, and at age sixteen entered the University of Caen. In 1767, on the recommendation of the mathematician Jean le Rond D'Alembert, whom he had sent an impressive paper on mechanics, he was appointed a professor at the École Militaire in Paris. Early in his career he also worked with the renowned chemist Antoine Lavoisier on the measurement of the specific heats of various substances.

In 1773 Laplace attacked a problem left unsolved by Newton: why the orbit of Jupiter shrinks while the orbit of Saturn expands. In a report published in three parts (1784–1786), Laplace showed that this phenomenon operates on a cycle of 929 years and arises because the mean motions of the two planets are nearly commensurable. This report also established the permanence and stability of the solar system for all time, thereby refuting Newton's belief that some sort of divine force was necessary to keep the system in its present state.

In 1787 Laplace presented to the Academy of Sciences an important paper on the acceleration of the moon. He showed that the gravitational influence of other planets on the orbit of the Earth affects the motion of the moon.

In 1796 he published his *Exposition of a World System*, a general and popular work containing his celebrated nebular hypothesis that the sun began as a giant nebula, or cloud of gas, in motion. His important work *Celestial Mechanics* (five volumes, 1799–1825) summarized the

For his many contributions to mathematics and astronomy, Pierre Laplace was elected to the French Academy in 1816 and became its president the following year.

writings of many other astronomers on the subject of gravitation. In 1812 he wrote a treatise that introduced important new ideas in pure mathematics and made him the founder of the modern application of the theory of probability.

Pierre Laplace

Napoleon I appointed Laplace minister of the interior in 1799 but removed him from that post within a few weeks and appointed him to the senate instead. Later, Laplace was made a count of the empire, and after the Bourbon restoration he became a marquis. He was also honored with election to the Academy of Sciences in 1785 and to the French Academy in 1816, becoming president of the latter body the following year.

LAUE, MAX THEODOR FELIX VON
(1879–1960)

The work of the German physicist Max von Laue was fundamental to the development of x-ray spectroscopy and the science of crystal-structure determination. For his work on the diffraction of x-rays in crystals he was awarded the 1914 Nobel Prize in physics.

At the time that Laue was conducting his investigations, x-rays were suspected to be electromagnetic wavelengths of extremely short duration, but their exact length was unknown. To accurately measure their length, a finely ruled grating was needed for their diffraction. Laue had learned of the lattice theory and suggested using a crystal for a grating, since crystals consist of layers of regularly spaced atoms. In 1912 the actual experiment was carried out by W. Friedrich and P. Knipping working under the guidance of Laue, and it was soon taken up and expanded by W. H. and W. L. Bragg and Karl Siegbahn.

Laue specialized in theoretical physics and was an enthusiastic supporter of Einstein's theory of relativity. He contributed to the development of the quantum theory and to the theories of electromagne-

tism and of the diffraction of light and also studied the Compton effect. Many of his articles were published in daily newspapers and scientific journals.

He was born at Pfaffendorf, near Coblenz, Germany, the son of an army official. Since the family moved from place to place during Laue's younger years, he attended many different schools. He received his higher education at the universities of Strasbourg, Göttingen, and Munich and in 1903 was awarded his doctorate from the University of Strasbourg. From 1905 to 1909 he worked as an assistant to Max Planck at the Institute for Theoretical Physics in Berlin and then went to the University of Munich, where he began his work on x-rays. He became a professor at the University of Zürich in 1912, at the University of Frankfurt in 1914, and at the University of Berlin in 1919, holding that post until 1943, when he resigned in protest against the Nazi regime. In 1951 he was appointed director of the Max Planck Institute for Physical Chemistry in Berlin.

LAVERAN, CHARLES LOUIS ALPHONSE
(1845–1922)

The 1907 Nobel Prize in physiology or medicine was awarded to Charles Laveran, a French physician and parasitologist, who was the first person known to describe the malarial parasite and to recognize it as the cause of the disease. In his military practice, as well as at the Pasteur Institute in Paris, he was a strong influence in the development of tropical medicine.

Laveran, the son of an army physician, lived with his parents in Algeria from 1850 to 1855 and thereafter attended schools in Paris, the place of his birth. After receiving a medical degree from the university of Strasbourg, France, in 1867, he practiced for a time in hospitals at Paris and Lille. During the Franco-Prussian War (1870) he served as an army surgeon in Metz and thereafter continued to practice military medicine and teach it until 1897, when he joined the Pasteur Institute, remaining there for the rest of his life.

Assigned to Algeria in 1878, Laveran began to study malaria, one of the most ancient infections known to man. In 1880 he discovered the causative factor and recognized it as a protozoan rather than a bacterium. This was the first time that a one-celled animal was shown to cause a disease.

Laveran wrote and published more than 600 scientific papers and textbooks, contributing important information about protozoan diseases. In 1907 he established the Laboratory of Tropical Diseases at the Pasteur Institute, and in 1908 he founded the Societé de Pathologie Exotique.

His honors included election to the French Academy of Medicine in 1898 and the French Academy of Sciences in 1901. He was made a commander of the Legion of Honor in 1912.

LAVOISIER, ANTOINE LAURENT
(1743–1794)

The French scientist Antoine Lavoisier is known as the Father of Modern Chemistry. His knowledge of the composition of water led to the beginnings of quantitative analysis. He elaborated the modern concept of an element, carried out early investigation in thermodynamics, and overthrew the phlogiston doctrine.

Lavoisier was born in Paris, the son of a wealthy lawyer. He received an excellent education at the Collège Mazarin, studying law, mathematics, astronomy, and chemistry.

His early scientific achievements included an analysis of the composition of gypsum, an experiment that disproved an ancient idea that water heated long enough would be converted into soil, and the discovery of dephlogisticated air, or oxygen. Finding that phosphorous and sulfur increased in weight when burned, he suspected that some material had been gained from the air. To Lavoisier combustion was the result, not of the liberation of the phlogiston, but of the combination of the burning substance with oxygen.

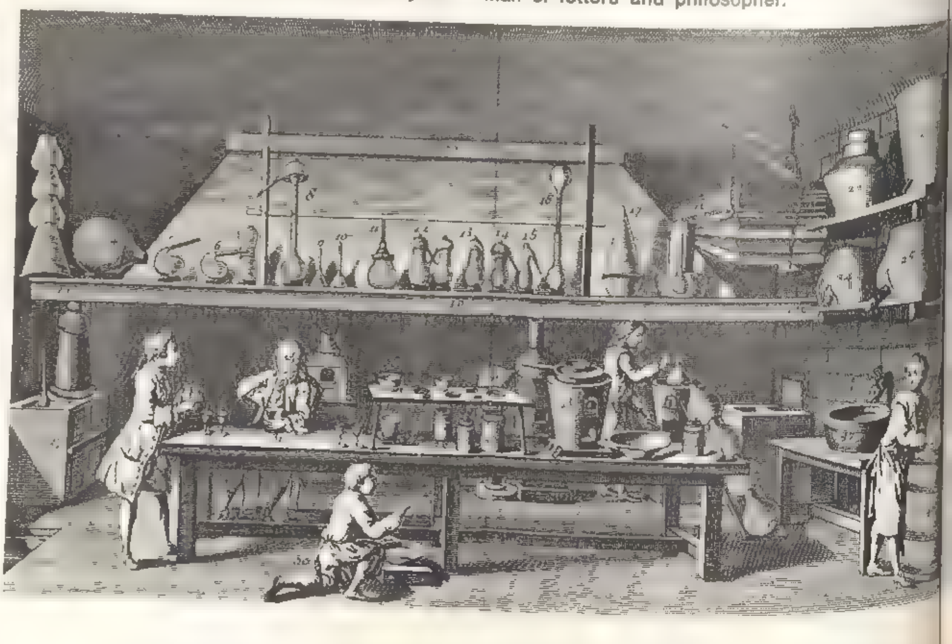
In 1783 he declar[illegible]hat water consists of hydrogen and ox[illegible], and this knowledge led to quantit[illegible] organic analysis. He was able to de[illegible]ine the composition of organic [illegible]ounds from the weight of the wat[illegible] carbon dioxide produced when [illegible]ompounds were burned in oxygen[illegible]

With Pierre La[illegible] Lavoisier conducted some of th[illegible]st thermochemical experiments a[illegible]ented an apparatus for measur[illegible]ar and cubical expansions. He a[illegible] extensive work in fermentation, r[illegible]on, and animal heat.

Lavoisier's the[illegible]ere widely accepted, largely be[illegible] they were explained thoroughl[illegible]ccurately, exact measurement bein[illegible]vays the rule. They were further [illegible]ad by his *Elementary Treatise* [illegible] *Chemistry*. This work, which also co[illegible]ned a list of simple elements, is con[illegible]d the first modern chemical textl[illegible]

Lavoisier was int[illegible] as much in the practical applicatio[illegible]hemistry as in making new discov[illegible] As a result, he was involved in m[illegible]tivities, mainly governmental, to i[illegible] social conditions in France. In [illegible] he designed a plan for lighting a [illegible] at night. Two years later he deve[illegible] a model farm, showing how scient[illegible]iculture could be used to get the [illegible]sults from the land and facilities. I[illegible]also a member of a governmental co[illegible]ee on agriculture to improve culti[illegible]n methods and of committees invol[illegible] with public health, coinage of money, and public education. As a memb[illegible] of the French provincial assembly of Orléans in 1787, Lavoisier set up a plan to improve social

Typical of the laboratories of Antoine Lavoisier's time is one that appears in the *Encyclopédie* (1751–1772) of Denis Diderot, French man of letters and philosopher.



Antoine Lavoisier

and econom nditions through savings banks and rance societies; and in 1790 he was etary of the commission responsible establishing uniformity of weights d measures throughout France.

One such olvement in affairs other than scient was disastrous for Lavoisier. He b me a member of a private organizatio nployed by the French governmen collect taxes. These tax farmers, as were called, took everything they ld from the farms and became ha by the public. Although Lavoisier v ot directly involved in the tax collect he was a supporter of the organizatio and his wife was the daughter c e of its executives. When the Frenc volution broke out, the tax farme re one of the main targets of the re onists, and Lavoisier was arrested. s trial he was accused of many acts had not committed and, as a result, w guillotined with his father-in-law an venty-six others. The radicals were o rthrown a few months later, but it was too late. The death of Lavoisier is considered by some historians the worst single casualty of the Revolution.

LAWRENCE, ERNEST ORLANDO (1901–1958)

The U.S. physicist Ernest Orlando Lawrence invented the cyclotron, a device for accelerating nuclear particles to high speeds. For that achievement and for his research on artificial radioactive elements he was awarded the 1939 Nobel Prize in physics. His cyclotron was cited as an extremely important research tool not only in physics but also in chemistry, biology, and medicine.

Lawrence, the son of a school administrator in Canton, South Dakota, received a bachelor's degree from the University of South Dakota in 1922 and a doctorate from Yale in 1925. At the latter institution he was a National Research fellow in physics from 1925 to 1927 and served for a time as assistant professor of physics. In 1928 he was appointed associate professor at the Berkeley campus of the University of California and in 1930, at the age of twenty-nine, full professor. Six years later he became director of the radiation laboratory at Berkeley, serving in that post until his death.

A major problem of nuclear physics in the 1920s was finding improved methods of bombarding atomic nuclei in order to produce nuclear transformations in even the heaviest nuclei. Lawrence built a device in which protons traveled between the poles of a large magnet that deflected their paths into circles. The protons received a boost of electric potential at each turn so that they moved ever faster in a spiral path that brought them closer to the rim of the instrument. Lawrence named his invention the cyclotron.

Wherever nuclear research was being pursued, the construction of cyclotrons was taken up. With the cyclotron a variety of new radioactive substances was produced and isolated, and the important field of radioactive tracer technique in medical, biological, and chemical research received a tremendous impetus.

Ernest Lawrence

Berkeley's first, second, and third cyclotrons, as well as several World War II cyclotrons used by the U.S. government, were built under Lawrence's supervision.

He was also a key figure in the development of the atomic bomb. In 1940, plutonium, an element centrally important in the history of atomic weapons, was isolated in his laboratory. Lawrence received the Enrico Fermi Award of the U.S. Atomic Energy Commission in 1957.

The Lawrence laboratory, known as a model of teamwork, attracted nuclear scientists from many countries. At the time of Lawrence's death it had a staff of more than 5,000. In 1961, element number 103 was detected in the laboratory that Lawrence had directed, and it was named lawrencium (Lw) in his memory.

LECLERC, GEORGES LOUIS. See Buffon, Comte de.

LEDERBERG, JOSHUA (1925–)

At the age of thirty-three the U.S. geneticist Joshua Lederberg won the 1958 Nobel Prize in medicine or physiology. The Nobel Prize is a crowning achievement in any man's life, but it seems a double honor so early in life. He shared the prize with Edward Lawrie

Joshua Lederberg

Tatum and George Wells Beadle. Lederberg had worked with Tatum to show that bacteria undergo sexual reproduction. They crossed different strains of bacteria and were able to combine the genetic material. Their work opened a new field of study: bacterial genetics. (*See* George Wells Beadle; Edward Lawrie Tatum.)

In 1952 Lederberg and one of his students discovered transduction, a process in which genetic material is moved from bacterium to bacterium by means of infecting virus particles. A man of far-reaching interests, Lederberg worked on the use of computers in chemistry, on molecular biology, and on astronomy, particularly the search for life on other planets.

He was born in Montclair, New Jersey, and received his bachelor's degree from Columbia University in 1944. After two years at its medical school, he went to Yale University to work with Tatum. He never went back to medical school as a student, instead taking his doctorate at Yale in 1948. From 1947 to 1959 he was on the faculty of the University of Wisconsin, with a year's leave in 1957 to serve as Fulbright Visiting Professor of Bacteriology at Melbourne University in Australia. In 1959 he accepted the position of chairman of the Department of Genetics at the Stanford University Medical School, Palo Alto, California.

LEE, TSUNG-DAO (1926–)

The Chinese-American theoretical physicist Tsung-Dao Lee shared the 1957 Nobel Prize in physics with Chen

Ning Yang for discovering that the principle of the conservation of parity does not hold true in all cases. This they demonstrated to be particularly true of weak interactions involving strange particles and neutrons. (*See* Chen Ning Yang.)

Tsung-Dao Lee

Since the late 1920s, physicists had assumed the existence of parity conservation, or the principle of space reflection symmetry. Working with the double breakdown of the K-meson, Lee and Yang concluded in 1956 that there is only one K-meson and that in weak interactions there is no conservation of parity. With the aid of another Chinese physicist they demonstrated this experimentally, which had great impact on the physics of elementary particles. Lee also did important work in astrophysics, field theory, nuclear and subnuclear physics, statistical mechanics, and turbulence.

He was born in Shanghai, China, and educated at the National Chekiang University at Hankow and the Southwest Associated University at K'unming. In 1946, on a scholarship from the Chinese government, he went to the United States to study and in 1950 received his doctorate in physics from the University of Chicago, where he then worked for a short time as a research associate in astronomy before joining the faculty of the University of California at Berkeley. He became a member of the Institute for Advanced Study, Princeton, New Jersey, in 1951 and with Yang, whom he had known previously at Chicago, began working on the problems of the conservation of parity. Lee was appointed an assistant professor of physics at Columbia University in 1953, an associate professor in 1955, and a full professor in 1956. He went back to the Institute for Advanced Study in 1960, working there as a professor of physics until 1963, when he returned to Columbia University. In 1964 he became a member of the National Academy of Sciences.

LEEUWENHOEK, ANTON VAN
(1632–1723)

Although the Dutch microscopist Anton van Leeuwenhoek was not the inventor of the microscope, his investigations more than anyone else's stimulated popular interest in microscopy. For this reason he is often regarded as the founder of microscopy. His observations went far beyond those of any other scientist of his time, and he is credited with having discovered bacteria and protozoa. The revelations of his lenses, incredible for that time, made him world famous. He was even visited by the queen of England and the czar of Russia.

Leeuwenhoek was born at Delft, Holland. He had very little formal education and no scientific training at all. At age sixteen he was apprenticed to a draper in Amsterdam, but after several years he returned to Delft—where he spent the rest of his life—and set up his own shop. Later he also worked as custodian at the city hall there.

As a hobby Leeuwenhoek took up lens grinding and made his own microscopes, producing more than 400 lenses in his lifetime. His simple microscopes consisted of a single lens. The lenses were ground with such precision, however, that some of his microscopes could magnify up to almost 200 times. In addition, he had a secret method of making objects visible that were too tiny to be seen with the naked eye. His method was never revealed; but there has been speculation that it was some type of dark-ground illumination or that the objects he viewed were contained in drops of liquid, which tends to improve visibility through lenses such as he used.

Leeuwenhoek's observations followed no scientific plan. He simply looked at all types of small materi[illegible]s under his microscopes and describe[illegible]hat he saw but with amazing accura[illegible]n 1668 he confirmed M. Malpigh[illegible]scovery of blood capillaries, and in [illegible] observations of blood went on to [illegible]he first accurate description of red [illegible] corpuscles, noting that they are ov[illegible]ed in the blood of birds, fish, and [illegible]nd disk shaped in the blood of hu[illegible]nd other mammals.

Anton van Leeuwenhoek

He opened pre[illegible]unseen worlds when he discover[illegible]ozoa and bacteria. His first desc[illegible]f protozoa appeared in 1674, a[illegible]llustration of bacteria was publis[illegible]683. He called these tiny forms of [illegible]nimalcules. In 1677 he gave the fir[illegible]cription of the spermatozoa of m[illegible]s. He also described striated mu[illegible]fibers and the crystalline lens of t[illegible]. He observed hydra, discovered r[illegible]s, found that yeast is composed of [illegible]all globular particles, and noted the st[illegible]ural differences between dicotyledonous and monocotyledonous stems.

Another important advance made by Leeuwenhoek was his disproof of the notion of spontaneous generation. At the

One of the microscopes of Anton van Leeuwenhoek consisted of a simple lens set in a hole that was centered in place. The specimen to be observed was placed on the point of a pin at the center of the hole containing the lens and was viewed from the other side. The entire instrument was held in the hand and pressed against the observer's face.

time it was widely lieved that weevils sprang from grain lfish from sand or mud, and maggot spoiled food and other substances wenhoek studied the life cycles evils, fleas, ants, aphids, and shell d found that their generative proce ere as complete as those of larger

During his li he sent 375 communications to oyal Society, with which body he ommunicating in the early 1670s. 7 communications to the French ny of Sciences as well. In 1680 h elected a fellow of the Royal Socie the same year was also elected to rench Academy of Sciences.

LEIBNIZ, BARON OTTFRIED WILHELM (1646–1716)

Like a great other eminent mathematicians, the an philosopher and man of affairs ed Leibniz was not concerned chi th mathematics; in fact, he cultiva d explored the most varied scienc uch an extent that each alone wo ve sufficed to make him famous. H ins one of the greatest systemati kers of the modern world, a major ian, and an independent inventor fferential and integral calculus.

Leibniz was in Leipzig, Germany, to a family th centuries had served the Saxon go nent. From his father, who was prof of law and moral philosophy at g University, he inherited a passion for history. From an early age he showed that insatiable desire to learn that was the chief stimulus of his intellectual life. At the age of six, when his father died, he started to use the well-stocked library in his home to read whatever came to hand. After learning Latin on his own when he was eight, he went on to study Greek, which he soon knew well enough to be considered an exceptional Hellenist.

He began his university studies at age fifteen and studied philosophy at Leipzig, then mathematics at Jena, and finally law, again at Leipzig. His degree thesis, which he was ready to defend at twenty, was a study of the teaching of law. It was refused at Leipzig, however, under the pretext that twenty was too tender an age. Altdorf University, on the other hand, immediately accepted his thesis and offered him the chair of law; but he refused it.

During a stay in Nürnberg he came into contact with the occult sciences and alchemy and met an influential politician, Baron von Boyneburg, through whose patronage he was appointed counselor of the Mainz Supreme Court in 1667. This marked the start of Leibniz' activity as a diplomat, a career for which he showed such outstanding aptitude that he was soon entrusted with a mission to Paris (1672). In order to avert the impending French threat to Germany and the Turkish threat to Europe, he was to convince Louis XIV of the advisability of French expansion in Egypt.

Although the plan failed as a result of the opposition of Louis XIV, this stay in the French capital, which at that time was one of the most famous intellectual centers in Europe, had a decisive influence on the development of Leibniz' scientific ideas and enabled him to meet the most interesting and influential personalities of the time. In 1672 he made the acquaintance of Christiaan Huygens, which was extremely important for him. Fascinated by the way in which mathematics could provide a solution for many physics problems—for example, that of the movement of pendulums—Liebniz asked Huygens to give him lessons in mathematics. Huygens agreed, and within four years Leibniz had made such important discoveries in the field of mathematics that he proved himself the equal, and even the superior, of Sir Isaac Newton himself.

Leibniz' numerous diplomatic duties often took him on trips through England. Traveling in those days—in uncomfortable stagecoaches, on rough roads, and in constant fear of highwaymen—was certainly not easy. Yet, apparently, Leibniz was able to think and write perhaps better while journeying than at home; in fact, many of his works were conceived during these travels. While in London in 1673, he encountered new mathematical problems that encouraged him to pursue his studies still further. He presented the calculating machine that he had built to the Royal Society, and soon afterward he was made a member. The machine was a great improvement on Blaise Pascal's because it could carry out all four operations and even extract roots.

The invention of the techniques of calculus took place in the period that immediately followed. Leibniz presented

A volume of Gottfried Leibniz' letters on mathematics appeared in Berlin in 1899.

Der Briefwechsel

von

Gottfried Wilhelm Leibniz

mit Mathematikern.

Herausgegeben

von

C. I. Gerhardt.

Mit Unterstützung der Königl. Preussischen Akademie der Wissenschaften.

Erster Band.

Mit einem photographischen Facsimile

Berlin.

Mayer & Müller.

1899.

calculus in its modern form, with the notations that are still in use today; and the simplicity of its symbolism favored its rapid diffusion throughout Europe. At the same time, however, Newton was formulating the fundamental notions of infinitesimal calculus; and soon there were reciprocal accusations of plagiarism. Both Newton and Leibniz were absolutely original in their thought, but the senseless polemic took a long time to die.

In 1677 Leibniz left England to return

Gottfried Leibniz

to Germany, where he had been appointed to the service of John Frederick, the Guelph duke of Brunswick-Lüneberg, and spent the last forty years of his life as adviser, archivist, historiographer, and tutor to the House of Brunswick. He turned his encyclopedic mind to philology, law, theology, psychology, ethics, and mathematics and kept up a learned correspondence on all these subjects with the greatest thinkers of the time. Since he considered that isolation impeded scientific progress, he planned and founded many societies and academies. Dreaming of an ideal union of all the peoples of the world, he predicted the adoption of a universal language. He also worked, long and in vain, for a reconciliation between church groups. In 1712 he was made a baron and an imperial privy councilor.

Besides his published works, Leibniz—with his restlessness, exactness, and extreme versatility—left a great many others that were unfinished. These writings are waiting in the library in Hanover for some scholar to make an appraisal of their contents and importance.

LELOIR, LUIS FEDERICO (1906–)

The naturalized Argentine biochemist Luis Federico Leloir won the 1970 Nobel Prize in chemistry for discovering sugar nucleotides and their part in the biosynthesis of carbohydrates. The Swedish Academy of Sciences described his research as fundamental to the understanding of the working of the human body.

Sugar nucleotides, of which more than 100 are known, act as catalysts in body chemistry, transforming one sugar into another. They are key substances in the storage of energy in animals, and starches in plants. Leloir's discoveries clarified the mechanisms of all the syntheses of compounds belonging to the carbohydrate group. Upon winning the Nobel award, he expressed the hope that his work would prove useful in the future treatment of diabetes.

Leloir was born in France but later became a citizen of Argentina. After receiving his medical degree from the University of Buenos Aires in 1932, he started his research at the university's Institute of Physiology under the direction of Bernardo A. Houssay, an Argentine who later won the 1947 Nobel Prize in medicine or physiology. At Houssay's suggestion, Leloir went to England for a year to broaden his background at the illustrious biochemical laboratory of Cambridge University.

When political events in Argentina led to the dismissal of Houssay and other professors in 1943, Leloir resigned his position at the University of Buenos Aires and went to the United States, working successively as research associate in the Department of Pharmacology, Washington University, Saint Louis, Missouri, and at the College of Physicians and Surgeons, Columbia University, New York City. Upon his return to Buenos Aires in 1946, he became head of the new Biochemical Research Laboratory-Campomar Foundation, where he and his colleagues later discovered sugar nucleotides.

In his research Leloir reached the conclusion that the transformation of one sugar into another sugar requires the presence of some substance that had yet to be identified. He isolated the substance, which turned out to be a compound of an unknown type. When he had solved its function in the sugar transformation, Leloir realized that he had uncovered the mystery of a great number of metabolic reactions.

Leloir's honors included foreign membership in the U.S. National Academy of Sciences (1960) and the American Academy of Arts and Sciences (1961). He received honorary degrees from the universities of Paris, France; Granada, Spain; and Tucumán, Argentina.

LENARD, PHILIPP EDUARD ANTON VON (1862–1947)

The German physicist Philipp von Lenard was the first scientist to study the properties of cathode rays penetrating through the cathode-ray tube into the outside air. This research won him the 1905 Nobel Prize in physics.

Lenard was born [illegible] Pozsony, Austria (now Bratislava, Czechoslovakia), and studied physics at Budapest, Vienna, and Berlin before receiving his doctorate in 1886 from the University of Heidelberg. In 1893 he became [illegible] assistant to Heinrich Hertz at the University of Bonn, in 1894 a professor at [illegible]au, and in 1895 a professor at Aachen. After serving as professor of theoretical physics at the University of Heidelberg from 1896 to 1898, he was appointed professor of experimental physics [illegible] but in 1907 returned to Heidelberg, where he remained until his retirement in 1931. After 1909 he also served as [illegible] of the Radiological Institute at Heidelberg.

Quite early in life Lenard became interested in cathode rays. Using Hertz's discovery that cathode rays penetrate thin layers of metal, Lenard constructed a cathode-ray tube with a thin aluminum window, which enabled the rays to pass through the aluminum and into the outside air. He measured and studied the properties of these [illegible] cathode rays, which were named after him, and noted how they ionized the air up to eight centimeters away. His investigations of photoelectricity revealed that ultraviolet light can cause cathode rays, which are electrons, to be released from metal plates. This work was important to the advancement of the theory of atomic structure and led Lenard to believe that atoms were mostly empty space.

Lenard also studied phosphorescence, as well as the electrification of falling water drops, devised a grid for controlling electron flow in a thermionic valve, and introduced the concept of ionization potentials. In his work with phosphorescence he found that it is caused by the return of electrons to the metallic impurities from which they have been emitted by exposure to light.

Although he was a brilliant scientist, Lenard had certain peculiarities of personality, being overly concerned about his own reputation as a physicist, as well as openly anti-Semitic. He was one of the few distinguished German scientists to subscribe to the philosophy of the Nazi government and denounced Jewish scientists, including Albert Einstein, whose theory of relativity he would not accept.

LEONARDO. See Da Vinci, Leonardo.

LESSEPS, FERDINAND DE (1805–1894)

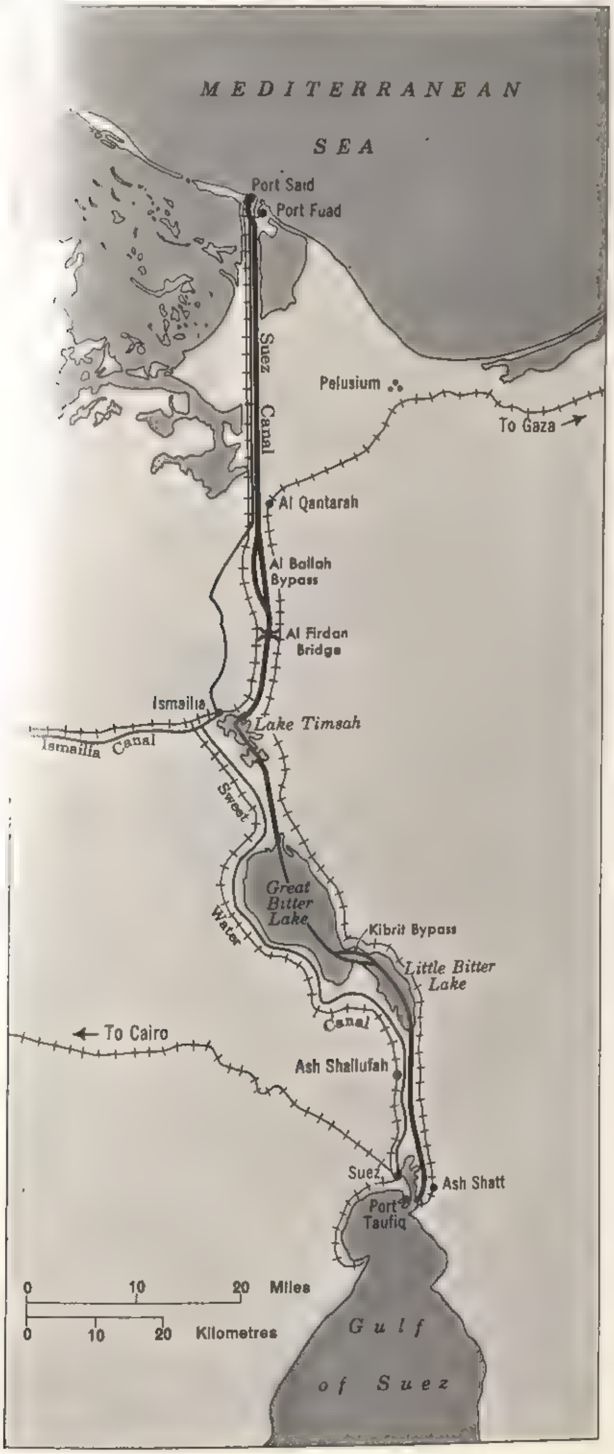
The man most responsible for the construction of the Suez Canal in Egypt was the French diplomat Ferdinand de Les-

seps. Through his untiring efforts he convinced the Egyptian ruler of the importance of the project, raised the needed money, and hel- d found the company that carried out he canal's construction. Late in his life seps was also involved in an unsucc l attempt to build a canal across th hmus of Panama.

Lesseps was at Versailles, France, the son of a omat. He followed his father into th lomatic corps and in 1825 was ap d assistant vice-consul at Lisbon, P l. Two years later he was sent to T , Tunisia, and in 1832 to Alexandria, Egypt. After serving as French consul in Cairo, he held various diplomatic posts in Europe and eventually was promoted to the rank of consul general. His diplomatic career ended in 1849 when he was sent to negotiate with the new republican government in Italy. The mission was a failure, and Lesseps was wrongly censured for his conduct during the affair. Consequently, he resigned, but this marked the beginning of his career as an administrator of one of the world's greatest engineering projects.

Lesseps first seriously considered the possibility of building a canal across Suez in 1832 while he was with the French consular service in Egypt. At that time he became friends with Mohammed Said, who granted the first canal concession on becoming khedive of Egypt in 1854. Using his diplomatic skill, Lesseps was able to get around the British opposition, win the approval of Napoleon III, and then proceed to raise the money for the project, half of which he obtained by public subscription. The project was begun in April 1859, and the canal was officially opened in November 1869. After its completion Lesseps was acclaimed by the French as a national hero.

The Suez Cana ects the Gulf of Suez on the Red Sea with the Mediterranean Sea.



In his next great project he was not so fortunate. He became interested in digging a canal across the Isthmus of Panama in 1879 and founded the Panama Canal Company, of which he was president from 1881 to 1888. He failed, however, to understand the difficulties of the task—refusing to believe that locks were necessary, despite the fact that the canal had to cross a mountain and a river—and the work went slowly, with many laborers dying of yellow fever. Finally, in 1888, the company was forced to liquidate. There was an official investigation into the matter in 1892, and Lesseps and his son were found guilty of having bribed French government officials. They were sentenced to five years in prison, but the sentence was never carried out because of an error in procedure.

Lesseps was a member of many scientific societies, the French Academy, and the Academy of Sciences. His honors included the Grand Cross of the Legion of Honor, the Star of India, and the Freedom of the City of London.

LEVERRIER, URBAIN JEAN JOSEPH
(1811–1877)

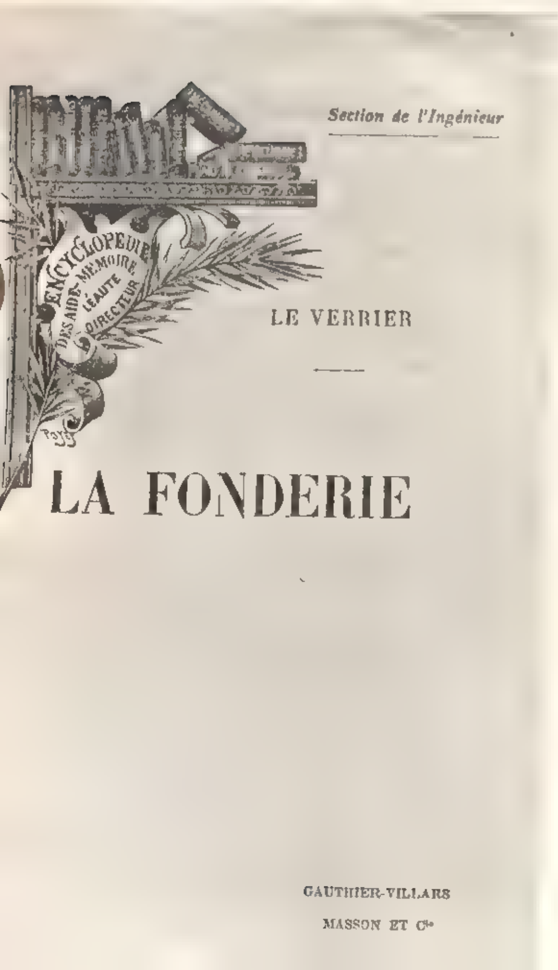
While studying the motions of the planet Uranus, the nineteenth-century French astronomer Urbain Jean Joseph Leverrier predicted the existence of the planet Neptune. He also revised planetary theories and compared theory with the best observations available at the time.

Leverrier was born in Saint-Lô, Normandy, the son of a government official. His distinguished scholastic career at the École Polytechnique in Paris was rewarded with a choice among the public service departments that were open to students of the school. He did chemical research until 1837, when he was offered a position as lecturer in astronomy at his alma mater.

Continuing the investigations of the great French mathematician and astronomer Pierre Simon Laplace, who had died in 1827, Leverrier proved the stability of the solar system. He also investigated the effects of slight variation of the elements of the planetary orbits on that stability; pursued an extensive study of Mercury, producing greatly improved tables of that planet; and did research on the perturbations of the comets. Then, while studying the planet Uranus, he noted in June 1846 that irregularities in its motion might be caused by the perturbing effect of an unknown planet and figured the size of the unknown planet and the position that it would have to occupy in order to account for the deviations. He received confirmation when, at Berlin, Germany, in September 1846, J. G. Galle discovered the planet Neptune within one degree of the place indicated by Leverrier.

A chair of astronomy was created for Leverrier at the Faculty of Sciences in Paris, and he was appointed adjunct astronomer to the Bureau of Longitudes.

La Fonderie was one of the works of the French astronomer Urbain Leverrier, who, thanks to the high quality of his observations, was able to predict the existence of Neptune.


Section de l'Ingénieur

ENCYCLOPÉDIE DES AIDE-MÉMOIRE LÉAUTÉ DIRECTEUR

LE VERRIER

LA FONDERIE

GAUTHIER-VILLARS

MASSON ET C^ie

Entering politics, he served as a member of the legislative assembly in 1849 and the senate in 1851 when he was inspector general of education. He was named director of the Paris Observatory in 1854, but his uncompromising rule led to his dismissal in 1870. Two years later, however, he was reinstated but with his authority restricted. In those turbulent years Leverrier worked out, with the greatest accuracy up to that time, a gravitational accounting of the motions of all the planets.


Urbain Leverrier

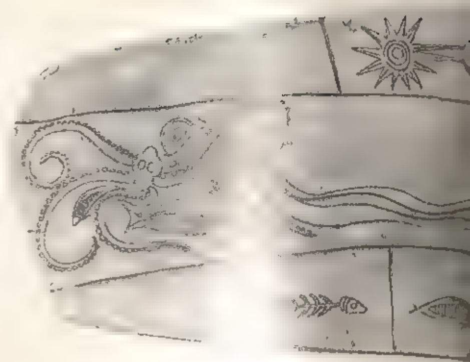
His one failure had great significance for the future of science. In 1845, while studying the motions of Mercury, he concluded that there had to be an undiscovered planet (which he called Vulcan) to account for the fact that Mercury was not quite where it belonged according to Newton's theory of gravitation and allowing for the perturbing effects of other planets. The planet Vulcan never was found nor is it believed to have existed; but the anomaly of Mercury's motion was one of the supports for Albert Einstein's general theory of relativity, which removed the mathematical necessity for Vulcan's existence.

Leverrier's work on the planet Mercury won him admission to the Paris Academy of Sciences in 1846. After the discovery of Neptune, Leverrier won many more honors—the Copley Medal of the Royal Society, the Gold Medal of the Royal Astronomical Society, the order of the Dannebrog from the king of Denmark, and membership in the Legion of Honor.

LIBBY, WILLARD FRANK (1908–)

The 1960 Nobel Prize in chemistry was awarded to the U.S. chemist Willard Frank Libby for conceiving and perfecting a technique that reveals the age of organic materials formed within the past 50,000 years. His radiocarbon dating produced valuable new information about the Earth and mankind.

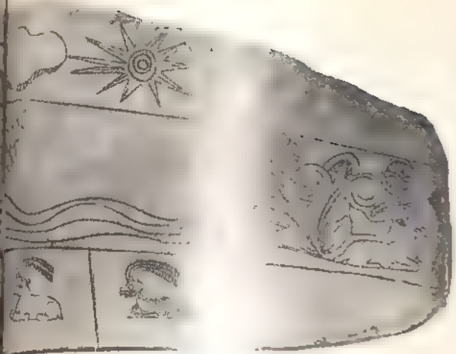
Libby, a farmer's son, was born in Grand Valley, Colorado, and studied chemistry at the University of California at Berkeley. After receiving his bachelor's degree in 1931 and his doctorate in 1933,


Radiocarbon dating, ... d in the 1940s at the University of Chi... Willard Libby, is based on the fact th... things contain a small amount of ca... which begins to

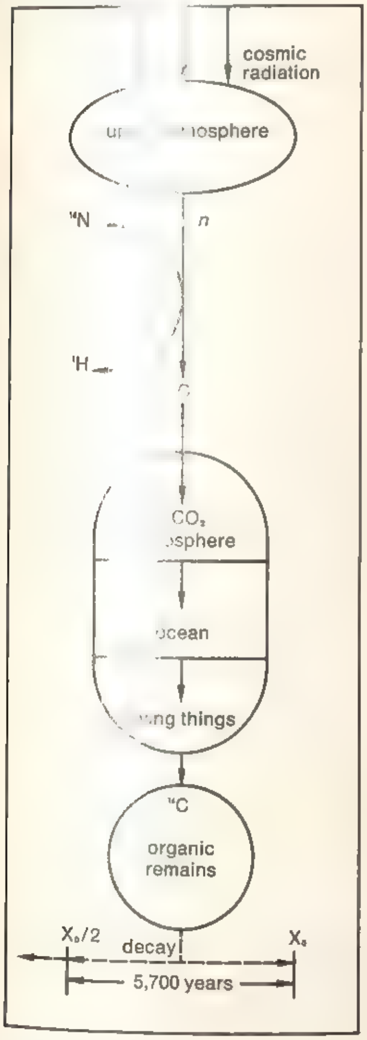
he taught chemistr... until 1940. During World War II ... working in the War Research Div... Columbia University, New York ... he helped develop the gaseous ... on method for separating the isot... f uranium. This was a basic step in ... cing the atomic bomb. After the wa... vent to the University of Chicago ... fessor of chemistry at the Institut... luclear Studies, where he develope... ocess for radiocarbon dating. In 1... was appointed to the U.S. Atomi... gy Commission and served until 19... n he joined the faculty of the Univ... of California at Los Angeles.


Willard Libby

Carbon-14, a radioactive isotope of carbon, was isolated in 1940 and was found to have a half-life of about 5,570 years. Half-life is the time required for disintegration of half the atoms in a given amount of a radioactive element. Carbon-14 was known to be formed by the interaction of cosmic rays from outer space with the nitrogen of the Earth's atmosphere. Because traces of carbon-14 are always present in the carbon dioxide of the air, which, in turn, is continuously being incorporated into all living matter, Libby reasoned that all living tissues and organic remains contain a measure of carbon-14. No additional carbon-14 is absorbed by the tissues after an organism dies, and what is already there begins to



decay at a known ... en an organism dies. This process ca... epresented diagrammatically or, in s... ses, artistically. One artist even used ... symbols.



break down at a known rate.

To detect and measure the faint emission of the decaying radiocarbon, Libby and his associates at the University of Chicago built an extremely sensitive Geiger counter in 1947. Comparisons of the amounts of carbon-14 in objects of known age—such as wooden artifacts from Egyptian tombs—with the amounts in living or recently dead samples of similar materials proved the validity of Libby's process. It is reliable back to about 50,000 years, which is as far into the past as radiocarbon can be measured.

During his years in Chicago, Libby and his students made many contributions to radiochemistry and to electron exchange reactions in aqueous solution. In 1947 Libby showed that cosmic rays produce tritium (radioactive hydrogen) and that measurement of tritium concentration can be used for dating well-water.

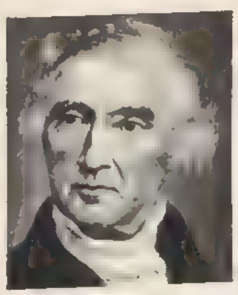
Libby was elected to the National Academy of Sciences in 1950 and received many awards, including the Chandler Medal of Columbia University, 1954, and the Albert Einstein Award, 1959. His writings include the book *Radiocarbon Dating* (1952).

LIEBIG, BARON JUSTUS VON
(1803–1873)

The nineteenth-century German chemist Justus von Liebig was instrumental in systematizing organic chemistry. He established a great school of chemistry based on laboratory instruction and also contributed to agricultural chemistry.

Liebig, a native of Darmstadt, was the son of a dealer in chemicals who liked to use them in amateur experiments. Pursuing his early interest in chemistry, Liebig studied at the University of Bonn with K. W. G. Kastner, a leading chemist of the time, and later followed him to the University of Erlangen, where he received his doctorate in 1822 at the age of nineteen. Awarded a grant from the Hessian government for study in Paris, France, Liebig worked in the private laboratory of the French chemist and physicist Joseph L. Gay-Lussac in 1823. The next year Liebig joined the faculty of the University of Giessen, Germany, becoming a full professor within two years. It was there that he set up his famous laboratory, attracting students from all parts of Europe. In 1852 he was appointed professor of chemistry at the University of Munich and concentrated increasingly on his literary activities thereafter.

Justus von Liebig



Early in his career Liebig met Friedrich Wöhler, another outstanding German chemist, with whom he collaborated in a number of investigations. Probably the most important was the study of bitter almond oil (benzaldehyde), which resulted in their theory of organic radicals that certain groups of atoms can act as a single unit in chemical reactions and in the formation of certain compounds. This theory was the first major attempt at systematization in organic chemistry. Seeing the need for reliable analytical methods, Liebig invented various kinds of chemical apparatus in the course of his research, including the Liebig condenser, which is used in laboratory distillation.

At the University of Giessen, Germany, Justus von Liebig set up a great school of chemistry based on laboratory instruction, which attracted students from all parts of Europe.

In the late 1830s Liebig's interest shifted from pure organic chemistry to the chemistry of plants and animals, or biochemistry. Among the agricultural innovations that he helped introduce were artificial fertilizers.

Liebig was a prolific writer; and much of his work was published in the journal that he founded in 1832, *Annals of Pharmacy*, which later became *Annals of Chemistry*. He also traveled and lectured widely in Europe. In 1840 he was elected a foreign member of the Royal Society, and in 1845 he was made a baron.

THE ILLUSTRATED SCIENCE DICTIONARY

Substance to Traprock

KEY TO PRONUNCIATION

The diacritical marks are:

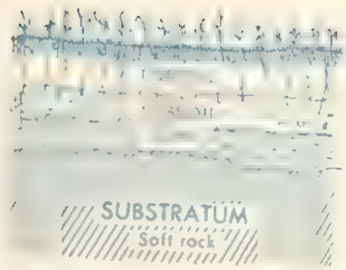
ə	b*a*nan*a*, *a*but	e	b*e*t	th	*th*in
ᵊ	preceding l, m, n as in batt*le*	ē	b*ea*t	t̲h̲	*th*en
ė	*e*lectric	i	t*i*p	ü	r*u*le, f*oo*l
ər	f*ur*ther	ī	b*i*te	u̇	p*u*ll, w*oo*d
a	m*a*t	j	*j*ob, *g*em	ue	German h*ü*bsch
ā	d*ay*	ŋ	si*ng*	u̅e̅	French r*ue*
ä	c*o*t, f*a*ther	ō	b*o*ne	yü	*u*nion
au̇	n*ow*, *ou*t	ȯ	s*aw*, *a*ll	zh	vi*si*on
		ȯi	c*oi*n		

ˈ mark preceding the syllable with strongest stress.
ˌ mark preceding a syllable with secondary stress.

The system of indicating pronunciation in these volumes is used by permission from Webster's *Third New International Dictionary*, copyright 1961 by G. & C. Merriam Co., Publishers of the Merriam-Webster Dictionaries.

substance \ˈsəb-stən(t)s\ *n.*
CHEMISTRY. Matter that has a definite chemical composition; also, an element or compound as distinguished from a mixture.

If a SUBSTANCE *can be broken down chemically into two or more simpler substances, it is a compound.*



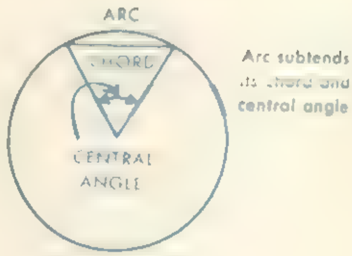
substituent \səb-ˈstich-(ə-)wənt\ *n.*
CHEMISTRY. An atom or group of atoms that replaces another atom or group of atoms in the molecule of a compound.

Chlorine is a SUBSTITUENT *in the reaction between methane and chlorine that produces chloromethane and hydrogen chloride.*

substitution ˌsəb-stə-ˈt(y)ü-shən\ *n.*
CHEMISTRY. Another term for replacement. See *replacement.*

substrate \ˈsəb-ˌstrāt\ *n.*
PHYSIOLOGY. A substance or material upon which organic catalysts (enzymes) act.

In the digestive process, the protein SUBSTRATE *is split by the pepsin enzyme produced in the stomach walls.*



SUBTEND

substratum \ˈsəb-ˌstrāt-əm\ *n.*
EARTH SCIENCE. A layer of earth or rock that lies directly under another layer.

Bedrock is often the SUBSTRATUM *that forms the parent material for the overlying soil.*

subtend \səb-ˈtend\ *v.*
MATHEMATICS. To be opposite to, or in an opposite position from.

In a circle, arcs SUBTEND *their central angles and their chords.*

SUBTERRANEAN
(CAVE)


subterranean \ˌsəb-tə-ˈrā-nē-ən\ *adj.*
EARTH SCIENCE. Referring to a natural object or occurrence beneath the surface of the earth.

SUBTERRANEAN *streams often come to the earth's surface through a fissure in rock, forming a spring.*

subtraction \səb-ˈtrak-shən\ *n.*
MATHEMATICS. The operation, or process, of finding the difference between two numbers or quantities.

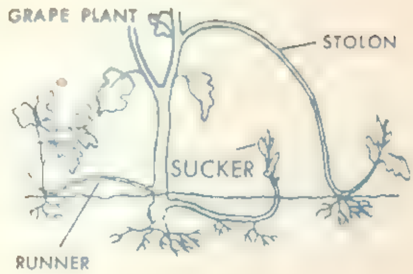
The answer to a problem in SUBTRACTION *is correct if the sum of the remainder and the subtrahend equals the minuend.*

subtrahend \'səb-trə-hend\ *n.*
MATHEMATICS. The quantity that is to be subtracted from another quantity, called the minuend.

In the problem 20 — 16 = 4, 16 is the SUBTRAHEND, *20 is the minuend and 4 is the difference.*

succession \sək-'sesh-ən\ *n.*
BIOLOGY. A series of changes in associations among and between plant and animal species that occupy a particular habitat. The changes may be caused by the effects species have on one another, by numbers of individuals or by geological conditions. The changes always proceed toward an equilibrium.

SUCCESSION *may take place over a period of several centuries, as an area of cleared land that changes first to a meadow and finally to a woods.*



sucker \'sək-ər\ *n.*
1. BOTANY. A usually fast-growing shoot from the lower stem or root of a plant. 2. ZOOLOGY. Any structure adapted for clinging or grasping through the use of unbalanced air or water pressures, as in flukes, leeches, octopuses and some fish.

If every SUCKER *of a tomato plant is removed, tall growth can often be stimulated.*

sucrose \'sü-ˌkrōs\ *n.*
BOTANY and CHEMISTRY. $C_{12}H_{22}O_{11}$. Ordinary table sugar obtained from the juice of sugar cane or sugar beets. Sucrose is an energy-producing food found in all known land plants.

In digestion, each molecule of SUCROSE *breaks down into simple sugars (one molecule of glucose and one molecule of fructose) before absorption into the blood.*

Monosaccharides (single sugars, $C_6H_{12}O_6$)	Disaccharides (double sugars, $C_{12}H_{22}O_{11}$)
GLUCOSE (DEXTROSE)	SUCROSE
FRUCTOSE	LACTOSE
	MALTOSE

SUGARS

sugars \'shu̇g-ərz\ *n.*
CHEMISTRY. A large group of crystalline organic compounds that may taste sweet when dissolved in water and that are composed of the elements carbon, hydrogen and oxygen; see *sucrose* and *glucose*.

SUGARS *are produced from carbon dioxide and water in all green plants.*

sulfa drugs \'səl-fə 'drəgz\
MEDICINE. A group of drugs containing an amino sulfane group, SO_2NH_2, that stops the growth of certain infectious bacteria. The group includes such drugs as sulfanilamide, sulfathiazole,

sulfadiazine and sulfapyridine. They are also called sulfonamides.

Sulfanilamide, the first of the SULFA DRUGS, *was a dye ingredient long before it was used as a drug.*

sulfate \\'səl-ˌfāt\\ *n.*

CHEMISTRY. Any one of many known compounds that contains the SO_4^{--} group, or radical. They are derived from sulfuric acid, H_2SO_4, by the replacement of one or both hydrogen atoms by one or more atoms or groups of atoms.

If a SULFATE *dissolves in water, the resulting solution will conduct electricity.*

IMPORTANT SULFATES
- Na_2SO_4 (sodium sulfate)
- $MgSO_4$ (magnesium sulfate)
- $CaSO_4$ (calcium sulfate)
- $CuSO_4$ (copper sulfate)
- $FeSO_4$ (iron sulfate)
- $ZnSO_4$ (zinc sulfate)

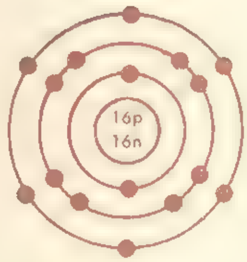
SULFATE

sulfur \\'səl-fər\\ *n.*

CHEMISTRY. A yellow, odorless, nonmetallic element that in nature may occur free or in metallic compounds. It is chemically active, burns with a blue flame, resembles oxygen in its chemical properties and is used in the manufacture of sulfuric acid, gunpowder, matches and vulcanized rubber. Symbol, S; atomic number, 16; atomic weight, 32.064.

The characteristic odor of sulfur water is not due to SULFUR, *but to hydrogen sulfide, a compound of sulfur.*

SULFUR ATOM



SULFUR

sulfuric acid \\ˌsəl-'fyu̇(ə)r-ik 'as-əd\\

CHEMISTRY. A strong acid that is a solution of hydrogen sulfate, H_2SO_4, in water. In concentrated form, it has a great attraction for water. It reacts with most metals to produce hydrogen and sulfate compounds.

Most SULFURIC ACID *is produced commercially by the contact process.*

sun \\'sən\\ *n.*

ASTRONOMY. The star at the center of the solar system, around which the earth and other planets revolve. It has a diameter of 864,000 miles, a surface temperature of about 5,500° C. and a mass 332,000 times that of the earth. It is about 93,000,000 miles from the earth.

Compared with other stars, the SUN *is about average in temperature and size.*

sunspots \\'sən-ˌspäts\\ *n.*

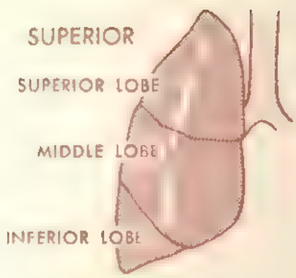
ASTRONOMY. Spots on the surface of the sun that usually have a dark inner region, or umbra, surrounded by a less-dark outer region, or penumbra. The spots have temperatures of about

4,000° C., while the average surface temperature of the sun is 5,500° C. They last from a few days to two or three months.

The electrical disturbance in the earth's atmosphere accompanying SUNSPOTS *may interfere with radio reception.*

superconductivity \ˌsü-pər-ˌkän-ˌdək-ˈtiv-ət-ē\ *n.*
PHYSICS. A state of little or no electrical resistance that is shown by such substances as lead and mercury when they are cooled to temperatures near absolute zero; see *absolute zero.*

The SUPERCONDUCTIVITY *of a lead ring permits an electrical current started in it to continue indefinitely without an outside supply of voltage.*



supercooled \ˌsü-pər-ˈküld\ *adj.*
CHEMISTRY and PHYSICS. Referring to a liquid that has been cooled below its freezing point without changing from liquid to solid form.

Most SUPERCOOLED *liquids will freeze quickly if shaken or if a small crystal of the solid form of the substance is added.*

superior \su̇-ˈpir-ē-ər\ *adj.*
1. ANATOMY. Referring to a structure or organ of the body located above some other part; also, sometimes, referring to a body structure directed upward. 2. ASTRONOMY. Referring to the planetary orbits or planets beyond the earth, as Mars, Jupiter, Saturn, Uranus, Neptune, and Pluto; also, referring to the conjunction of either Mercury or Venus when farthest from the earth.

In the human body, the right lung contains a SUPERIOR *lobe, a middle lobe and an inferior lobe.*

supernova \ˌsü-pər-ˈnō-və\ *n.*
ASTRONOMY. A star that appears to explode and that is sometimes bright enough to be seen in daylight. It may reach a brightness 100 million times the real brightness of the sun. Only three supernovas have been observed in our galaxy during the past 1,000 years.

The last SUPERNOVA *observed in the earth's galaxy, the Milky Way, was discovered A.D. 1604.*

superposition \ˌsü-pər-pə-ˈzish-ən\ *n.*
EARTH SCIENCE. A general law stating that younger rocks lie above older rocks if the rock layers have not been overturned.

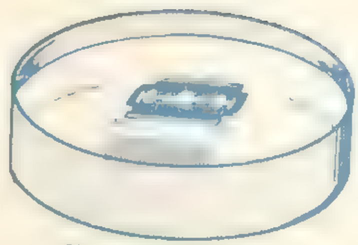
The law of SUPERPOSITION *has helped geologists determine the relative ages of various rock exposures.*

supersaturated solution \\ˌsü-pər-ˈsach-ə-ˌrāt-əd sə-ˈlü-shən\\
CHEMISTRY. An unstable solution containing more solute at a given temperature than a saturated solution contains at the same temperature.

A SUPERSATURATED SOLUTION *may often be changed to a saturated solution by shaking, causing the surplus solute to crystallize and settle out.*

superscript \\ˈsü-pər-ˌskript\\ *n.*
MATHEMATICS. A number, letter or other symbol written to the right of, and slightly above, another number or letter. A superscript is commonly used as an exponent.

The SUPERSCRIPT ^{4}, *in* 2^4, *means that 2 is to be used as a factor four times.*



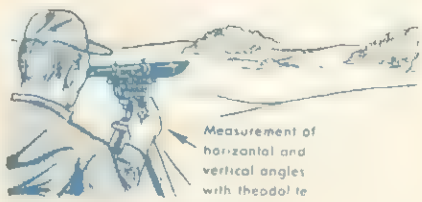
SURFACE TENSION

supersonic speed \\ˌsü-pər-ˈsän-ik ˈspēd\\
AERONAUTICS. Any speed greater than the speed of sound (Mach 1), which is approximately 760 miles per hour near the surface of the earth; specifically, those speeds between Mach 1 and Mach 5. Speeds faster than Mach 5 are called hypersonic.

An airplane flying at SUPERSONIC SPEED *moves faster than the sound it produces, causing a state of almost complete silence inside the airplane.*

surface tension \\ˈsər-fəs ˈten-shən\\
CHEMISTRY and PHYSICS. The property of a liquid surface that apparently forms a thin elastic film. Surface tension causes all free liquids to take a spherical shape unless other forces are present and results from the attractive forces, or cohesion, between molecules in and near the liquid surface.

If a razor blade is carefully laid on a quiet water surface, it will be supported by SURFACE TENSION.



SURVEY

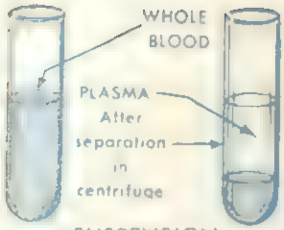
survey \\ˈsər-ˌvā\\ *n.*
EARTH SCIENCE. A measurement of the contour, position and location of points on the earth's surface relative to each other, performed so that natural or artificial features can be represented accurately on a drawing; also, the organization making the survey, or the data obtained.

A land SURVEY *is necessary in planning highway construction.*

survival of the fittest \\sər-ˈvī-vəl əv t͟hə ˈfit-əst\\
BIOLOGY. A part of Charles Darwin's theory of evolution, stating that only the better-adapted individuals of one generation live

long enough to become the parents of the next generation.

An example of SURVIVAL OF THE FITTEST *might be fast-swimming salmon that, unlike slower-swimming salmon, avoided being eaten by bears.*



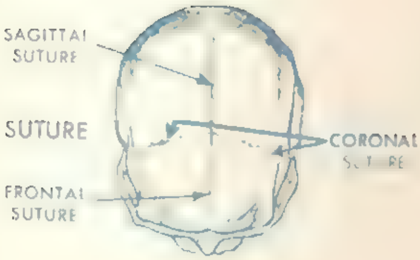
SUSPENSION

suspension \sə-'spen-chən\ *n.*
CHEMISTRY. A condition of undissolved particles when they are distributed throughout a liquid or gas. If the liquid or gas is left undisturbed, the particles will settle slowly.

In a laboratory, a centrifuge is often used to speed the separation of particles in a SUSPENSION.

suture \'sü-chər\ *n.*
1. ANATOMY and BIOLOGY. A line, division or seam marking the edges of two adjoining parts. 2. MEDICINE. Stitching that joins the edges of a wound or incision.

The SUTURE *across the top of a newborn infant's skull becomes fused early in childhood.*



SUTURE

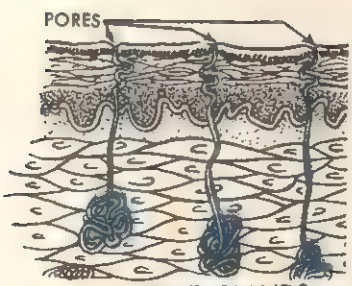
sweat glands \'swet 'glandz\
ANATOMY and PHYSIOLOGY. Tube-shaped organs in the skin that empty their secretions onto the surface of the body. These glands help cool the body by secreting a watery fluid that evaporates from the skin surface.

Under conditions of normal comfort, the SWEAT GLANDS *secrete about one pint of perspiration per day.*

swing wing \'swiŋ 'wiŋ\
AERONAUTICS. Another term for variable wing; see *variable wing*.

symbionts \'sim-ˌbī-ˌänts\
BIOLOGY. Two organisms that live together, one dependent on the other, or each benefiting the other, as in mutualism. If the two are very different in size, this term is used for the smaller; the larger is called the host.

A lichen is composed of plant SYMBIONTS, *one an alga and one a fungus.*



SWEAT GLANDS

symbiosis \ˌsim-ˌbī-'ō-səs\ *n.*
BIOLOGY. The close living together of two organisms of different species where the association benefits one or both, as in parasitism, commensalism and mutualism.

SYMBIOSIS *of mutual benefit is illustrated in the tickbird-rhinoceros relationship, in which the rhinoceros allows the tickbird to feed on its skin parasites.*

sympathetic nervous system \\ˌsim-pə-ˈthet-ik ˈnər-vəs ˈsis-təm\\

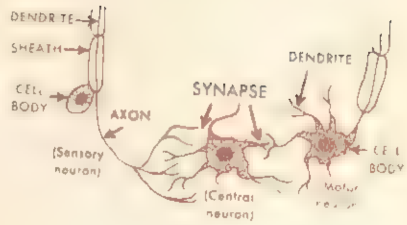
PHYSIOLOGY. A division of the autonomic nervous system that opposes and balances the involuntary actions of the parasympathetic nervous system on such organs as the heart, salivary glands, small intestine, stomach and eyes.

Both the SYMPATHETIC NERVOUS SYSTEM *and the parasympathetic nervous system function automatically.*

synapse \\ˈsin-ˌaps\\ *n.*

PHYSIOLOGY. In higher animals, the junction through which a nerve impulse passes from the axon of a neuron to the dendrite of another neuron.

A SYNAPSE *may include the junction of a number of axons from different neurons with the dendrite of a single neuron, or that of one branched axon with dendrites of several neurons.*



SYNAPSE

synchronous \\ˈsiŋ-krə-nəs\\

PHYSICS. Referring to an electric motor that operates at the same frequency of rotation as the frequency of the alternating current motivating it.

SYNCHRONOUS *motors are often used where constant speed must be maintained despite voltage fluctuations, as in electric clocks.*

synchrotron \\ˈsiŋ-k(r)ə-ˌträn\\ *n.*

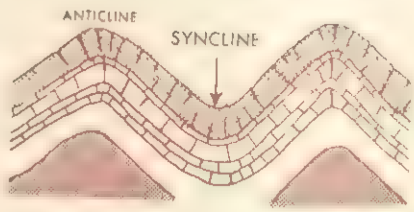
PHYSICS. A type of cyclotron used to accelerate subatomic particles; see *cyclotron* and *particle accelerator.*

A SYNCHROTRON *may give subatomic particles more than one billion electron volts of energy.*

syncline \\ˈsin-ˌklīn\\ *n.*

EARTH SCIENCE. A trough or downward fold in sedimentary rock strata; see *anticline.*

A SYNCLINE *is a rock structure that may form a mountain.*



SYNCLINE

syndrome \\ˈsin-ˌdrōm\\ *n.*

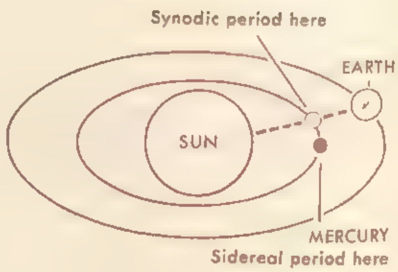
MEDICINE. A group of symptoms occurring together and indicating the presence of a specific disease or condition.

Different diseases do not have the same SYNDROME, *although their syndromes may be similar.*

synodic period \\sə-ˈnäd-ik ˈpir-ē-əd\\

ASTRONOMY. The time required for a planet to make one complete revolution around the sun with respect to the earth; see *sidereal period.*

Mercury's SYNODIC PERIOD *is 115.9 days.*



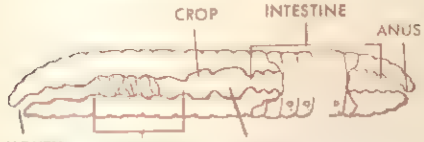
SYNODIC PERIOD

synthesis \'sin(t)-thə-səs\ *n.*
CHEMISTRY. A chemical reaction between two or more elements that forms a compound; also, a series of reactions that produces a given compound.

SYNTHESIS *of water is accomplished by reacting hydrogen and oxygen.*

synthetic \sin-'thet-ik\ *adj.*
CHEMISTRY. Referring to compounds produced by laboratory or industrial processes, as distinguished from natural substances that are produced by plants, animals or geologic processes.

Almost all tires are now made from various SYNTHETIC *rubber compounds.*



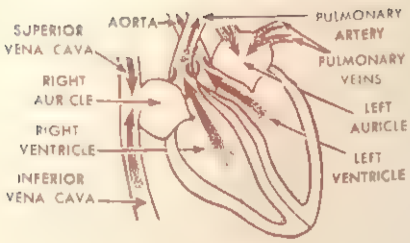
SYSTEM

system \'sis-təm\ *n.*
1. ANATOMY and ZOOLOGY. A group of organs having a related function, as in the circulatory system. 2. ENGINEERING. An interconnecting network of parts (components) that performs one or more specific functions, as the guidance system of a guided missile. 3. CHEMISTRY. A group of substances in which chemical or physical reactions, or both, occur and that contains both reactants and products. 4. EARTH SCIENCE. Layers or groups of rocks formed in a given period of geologic time; also, one of the six divisions in the classification of crystals according to their form. 5. ASTRONOMY. A group of related celestial bodies.

Even though it is a simple organism, the earthworm has a digestive SYSTEM *with many of the basic characteristics of the digestive systems of more complex animals.*

systemic \sis-'tem-ik\ *adj.*
PHYSIOLOGY. Referring to the entire body rather than to a particular portion or organ.

SYSTEMIC *blood circulation in man supplies all parts of the body with blood except the lungs.*



SYSTOLE

systole \'sis-tə-(ˌ)lē\ *n.*
PHYSIOLOGY. That stage in the heartbeat when the heart, especially the ventricles, contracts, forcing the blood into the arteries; see *diastole*.

SYSTOLE *is followed by a relaxation of the heart muscles.*

systolic blood pressure \sis-'täl-ik 'bləd 'presh-ər\
PHYSIOLOGY. The force per unit area exerted by blood on the walls of arteries when the ventricles of the heart are contracting.

SYSTOLIC BLOOD PRESSURE *is normally lower in young children than it is in adults.*

T

tachometer \ta-'käm-ət-ər\ *n.*

ENGINEERING. An instrument used to measure the rate of rotation of a spinning object, such as the drive shaft of an engine or an electric motor. It usually gives measurements in units such as RPM (revolutions per minute) or RPS (revolutions per second).

A TACHOMETER, *when used on an automobile, measures the speed at which the engine is operating while the speedometer measures the speed at which the whole car is moving.*

TACONITE

taconite \'tak-ə-ˌnīt\ *n.*

EARTH SCIENCE. A rock that contains 20 to 30 percent iron in the form of magnetite, Fe_2O_3; also, a low-grade iron ore found in the Mesabi Range in northern Minnesota.

TACONITE *is one of the known principal reserves of iron ore in North America.*

tactile \'tak-tᵊl\ *adj.*

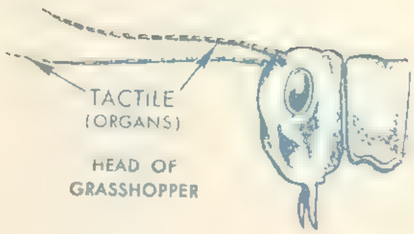
PHYSIOLOGY. Referring to the sense or organs of touch.

The antennae of grasshoppers have a TACTILE *function.*

tagged atoms \'tagd 'at-əmz\

CHEMISTRY and PHYSICS. Radioactive atoms whose location can be detected by a Geiger counter or a photographic film; also, radioactive isotopes of a normally nonradioactive element that are used to trace, or follow, the element in chemical reactions and in biological or physical systems; sometimes called tracers.

Studies with TAGGED ATOMS *of oxygen have shown that oxygen given off by plants during photosynthesis comes from water molecules taken in through the plant roots.*

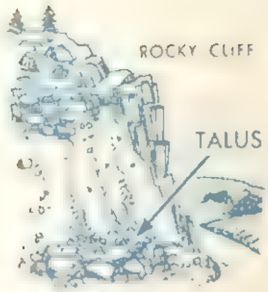


HEAD OF GRASSHOPPER

talc \'talk\ *n.*

EARTH SCIENCE. $Mg_3Si_4O_{10}(OH)_2$. A soft, greasy-feeling mineral composed of hydrous magnesium silicate and usually found in layered or compact masses. It is used in paints, ceramics, rubber, paper and cosmetics.

TALC *has a hardness of one on Mohs' scale, meaning that it will make a mark if rubbed against a piece of cloth.*



talus \'tā-ləs\ *n.*

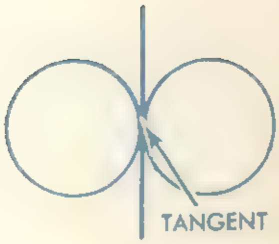
EARTH SCIENCE. A sloping accumulation or heap of rock fragments at the base of a cliff or steep slope; also, the rock particles in such a slope; also called scree.

A TALUS *is made up of rocks that were broken away from a cliff by frost action or by other weathering processes.*

tangent \'tan-jənt\

MATHEMATICS (Adj.). Touching a curved line or surface at one point but usually not crossing unless the point of touch is an inflection point. (N.). A tangent line; also, the trigonometric function of an acute angle of a right triangle that is the ratio of the side opposite the angle to the side adjacent to the angle; also, for any angle in standard position, the ratio of the ordinate of a point on the terminal side of the angle to the abscissa of that point.

TANGENT *circles are both tangent to the same line at the same point.*



tannin \'tan-ən\ *n.*

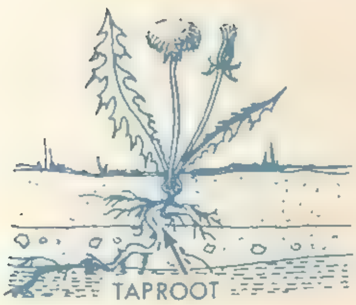
CHEMISTRY. Any one of several naturally-occurring organic compounds applied to animal hides to make them flexible and resistant to wear. Tannin occurs in various parts of plants, as in the bark of hemlock and some oak trees.

TANNIN *is used in the treatment of leather, the production of some inks and in certain medicines.*

taproot \'tap-ˌrüt\ *n.*

BOTANY. The main root of a plant that develops from the primary root and that grows vertically downward, giving rise to side roots.

The dandelion remains green during periods of drought because its TAPROOT *extends to depths where the soil is moist.*



tar \'tär\ *n.*

CHEMISTRY. An oily liquid produced by the destructive distillation, or incomplete burning, of organic materials, such as coal, wood and tobacco.

Creosote, obtained from wood TAR, *often is used to preserve telephone poles and railroad ties.*

tarn \'tärn\ *n.*

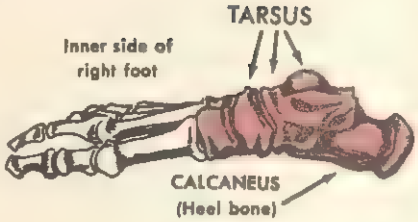
EARTH SCIENCE. A small lake that occupies a basin, or cirque, scraped out by a mountain glacier.

A TARN *is found high in the mountains where a glacier formed and later melted.*

tarnish \'tär-nish\ *v.*

CHEMISTRY. To dull the otherwise shiny surface of a metal. Tarnish is caused by a chemical reaction with oxygen or some other substance, which produces a thin film covering the metal.

Eggs often contain enough hydrogen sulfide to TARNISH *a silver spoon.*



tarsus \'tär-səs\ *n.*

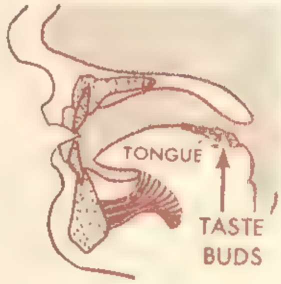
ANATOMY. The seven bones in the human foot making up the instep and located between the lower leg bones, or tibia and fibula, and the metatarsal bones in the foot.

The largest bone of the TARSUS *is the heel bone.*

tartar \'tärt-ər\ *n.*

PHYSIOLOGY. A hard substance that forms on teeth from the mineral salts in saliva. It is composed chiefly of calcium phosphate.

A dentist usually scrapes away deposits of TARTAR *before cleaning the teeth with a fine abrasive.*



taste buds \'tāst 'bədz\

PHYSIOLOGY and ZOOLOGY. In man and other vertebrates, the receptors for the chemical sense of taste, usually located in bundles on the upper surface and sides of the tongue. They seem to be receptive only to substances in solution that are sour, sweet, bitter or salty.

The flavor of a food is a combination of texture (detected by touch receptors in the tongue), odor (detected by chemical receptors in the nose) and taste (detected by the tongue's TASTE BUDS*).*

tear gland \'ti(ə)r 'gland\

PHYSIOLOGY and ZOOLOGY. In higher vertebrates, a gland located behind the upper eyelid at the outer corner of the eye. It produces a watery liquid that washes the eye surface; also called lachrymal gland.

Liquid from the TEAR GLAND *is distributed over the eyeball by blinking.*

technology \tek-'näl-ə-jē\ *n.*

That branch of human activity dealing with the application of science to practical purposes and sometimes called applied science.

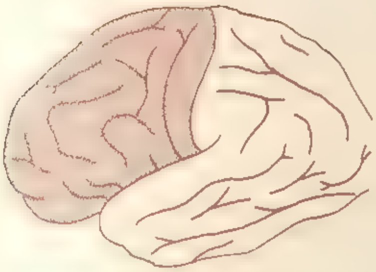
Through the related achievements of science and TECHNOLOGY*, we have improved health, housing and communication.*

tectonic \tek-'tän-ik\ *adj.*
EARTH SCIENCE. Referring to the processes, forces or structures involved in deforming the earth's crust.

Folding and faulting are TECTONIC *processes that have produced mountain ranges.*

telemetering system \'tel-ə-ˌmēt-ər-iŋ 'sis-təm\
ENGINEERING. A system that measures quantities in one location, such as in or around a balloon, rocket or artificial satellite, and, by means of radio equipment, permits the information to be recorded or observed at another location, such as a ground station.

The measuring and transmitting parts of a TELEMETERING SYSTEM *carried aloft by a weather balloon relay back information about temperature, relative humidity and atmospheric pressure.*



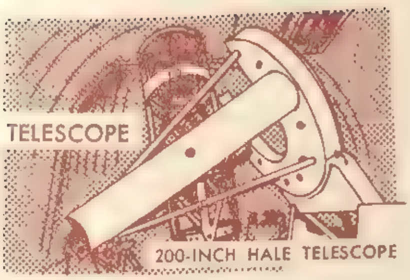
TELENCEPHALON

telencephalon \ˌtel-en-'sef-ə-ˌlän\ *n.*
MEDICINE and PHYSIOLOGY. The forepart of the brain; also, the cerebral hemispheres and the thalamus, which develop from the forepart of the embryonic brain.

The TELENCEPHALON *includes the largest and most conspicuous portions of the nervous system.*

telescope \'tel-ə-ˌskōp\ *n.*
ASTRONOMY and PHYSICS. A device using lenses and mirrors, or some combination of both, to produce magnified visual images of distant objects. In a simple form, a telescope has a large (objective) lens to collect and focus light and a second lens (eyepiece) to magnify the image.

The most important qualities of a TELESCOPE *are its light-gathering and resolution powers.*



TELESCOPE

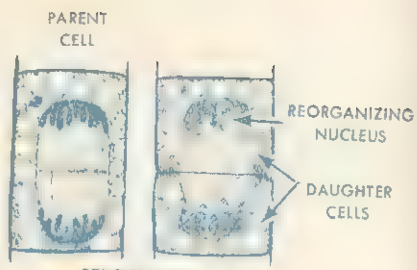
200-INCH HALE TELESCOPE

television frequencies \'tel-ə-ˌvizh-ən 'frē-kwən-sēz\
PHYSICS. The radio frequencies that carry television pictures and sounds; in the United States, frequencies from 55.25 to 87.75 megacycles, and from 175.25 to 215.75 megacycles.

FM radio frequencies lie between the two groups of TELEVISION FREQUENCIES.

telophase \'tē-lə-ˌfāz\ *n.*
BIOLOGY. The final stage of mitotic cell division, characterized by the division of the cytoplasm and the formation of nuclei in the resulting two cells.

Late in TELOPHASE, *the nucleolus that disappears during prophase reappears in the nucleus of each daughter cell.*



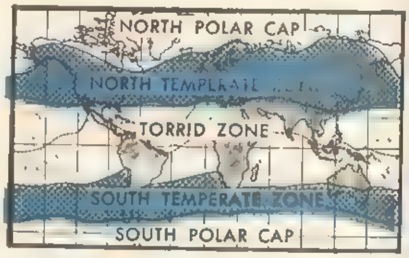
TELOPHASE

Temperate Zone \'tem-p(ə-)rət 'zōn\
EARTH SCIENCE. Either of two areas of the earth in the middle latitudes, north and south; the area between the Tropic of Cancer (23½ degrees north) and the Arctic Circle (66½ degrees north) and the area between the Tropic of Capricorn (23½ degrees south) and the Antarctic Circle (66½ degrees south).

Each TEMPERATE ZONE *has four seasons per year.*

temperature \'tem-pər-ˌchu̇(ə)r\ *n.*
PHYSICS. The intensity of heat energy in a given object or region of space. Temperature depends on the average kinetic (moving) energy of the molecules in a given space and may be expressed by using any one of several scales, such as Fahrenheit (°F.) or Celsius (°C).

The lowest TEMPERATURE *theoretically possible (absolute zero) is that temperature at which all molecular motion stops.*



TEMPERATE ZONE

temperature-humidity index \'tem-pərˌchu̇(ə)r-hyü-'mid-ət-ē 'in-deks\
EARTH SCIENCE. A relationship between the humidity and temperature of the atmosphere; sometimes called comfort index. At a value of 70, most people are comfortable, but at 80, most are uncomfortable.

The TEMPERATURE-HUMIDITY INDEX *may be computed by adding the dry-bulb temperature in °F. and the wet-bulb temperature in °F., multiplying the total by 0.4 and adding 15.*

temperature inversion \'tem-pər-ˌchu̇(ə)r in-'vər-zhən\
EARTH SCIENCE. An atmospheric condition existing when the air nearest the earth's surface is colder than the air above it.

A TEMPERATURE INVERSION *may cause fog to last for several days.*

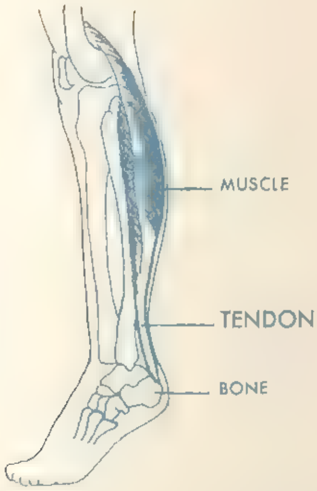
TEMPERATURE INVERSION

tempering \'tem-p(ə-)riŋ\ *n.*
ENGINEERING. A relatively low-temperature process in the heat treatment of steel that results in a balance of hardness and toughness. The process involves heating the steel and then cooling it suddenly, followed by a final heating.

The final heating phase in TEMPERING *causes distinctive colors of oxide film on steel, as the blue of some guns.*

temporary hardness \'tem-pə-ˌrer-ē 'härd-nəs\
CHEMISTRY. A condition of water resulting from the presence of salts of calcium and magnesium that can be removed by boiling. In this condition, water requires large amounts of soap to form suds.

TEMPORARY HARDNESS *of water in heating systems often causes a limelike deposit in pipes.*



tenacity \tə-'nas-ət-ē\ *n.*
EARTH SCIENCE. A mineral's resistance to breakage or the separation of its atoms.

The characteristics of hardness and TENACITY *together are called cohesion.*

tendon \'ten-dən\ *n.*
ANATOMY and ZOOLOGY. In vertebrate animals, a cord of strong, flexible, connective tissue in which the fibers of a muscle end and that connects the muscle to a bone or other structure.

In man, the Achilles TENDON *connects the calf muscles to the heel bone.*

tendril \'ten-drəl\ *n.*
BOTANY. A plant structure that wraps itself around an available support. It is usually a modified stem, as in grapes or gourds, or a modified leaf, as in sweet peas or vetches.

A TENDRIL *that coils after attachment tends to draw the plant close to the support.*

SWEET PEA

tensile strength \'ten(t)-səl 'streŋ(k)th\
PHYSICS. A measure of the force required to pull apart a given piece of material, determined by dividing the load (pounds) required to pull the object apart by its cross-sectional area (square inches).

The TENSILE STRENGTH *of steel piano wire is about 350,000 pounds per square inch.*

term \'tərm\ *n.*
MATHEMATICS. The numerator or denominator of the symbol (fractional numeral) that represents a fraction; also, any one of the numbers or expressions that is a part of a proportion; also, one of the quantities whose sum is a polynomial.

In the polynomial $y^2 + 3y + 8$, the first TERM *is y^2, the second is $3y$ and the third is 8.*

terminal moraine \'tərm-nəl mə-'rān\
EARTH SCIENCE. An end moraine. See *end moraine.*

terminal velocity \'tərm-nəl və-'läs-ət-ē\

PHYSICS. The greatest speed an object acquires while falling freely. It is a constant speed that occurs when the force of air resistance on a falling object equals the force of gravity.

A parachute jumper may reach a TERMINAL VELOCITY *of about 120 miles per hour.*

terminator \'tər-mə-,nāt-ər\ *n.*

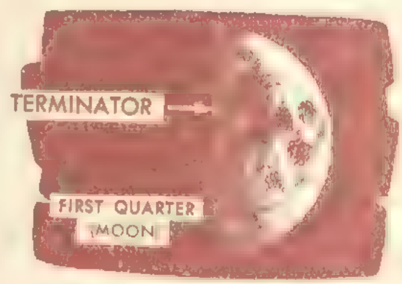
ASTRONOMY. The line, or border, separating the areas of day and night on the moon or the planets. The terminator marks the position of sunrise or sunset.

The TERMINATOR *on the moon is particularly noticeable when the moon is at first quarter and third quarter.*

ternary compound \'tər-nə-rē 'käm-,paủnd\

CHEMISTRY. A substance composed of three different chemical elements. Each of its molecules or crystals, therefore, contains three different kinds of atoms or ions.

Sulfuric acid, H_2SO_4, is a TERNARY COMPOUND *containing atoms of hydrogen, sulfur and oxygen.*



terpene \'tər-,pēn\ *n.*

CHEMISTRY. Any one of a group of easily-vaporized hydrocarbon compounds having the general formula $(C_5H_8)_n$, in which $_n$ is any whole number. Terpene occurs in many varieties of plants and may be obtained by distillation.

Camphor is a TERPENE *used in several medicinal preparations.*

terrestrial magnetism \tə-'res-t(r)ē-əl 'mag-nə-,tiz-əm\

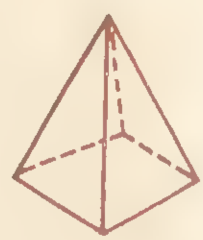
EARTH SCIENCE. The magnetic properties of the earth; see *magnetism* and *geomagnetism.*

TERRESTRIAL MAGNETISM *may be related to slowly-moving currents within the liquid part of the earth's core.*

tetraethyl lead \,te-trə-'eth-əl 'led\

CHEMISTRY. An organic lead compound added to gasoline in order to improve the antiknock properties (octane rating) of the gasoline. When it is added to gasoline, a second compound (1,2-dibromoethane) is added to prevent lead deposits in the engine; see *octane rating scale.*

Three milliliters of TETRAETHYL LEAD *added to one gallon of gasoline will raise the gasoline's octane number about 20 units.*



TETRAHEDRON

tetrahedron \,te-trə-'hē-drən\ *n.*

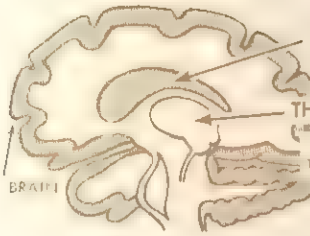
MATHEMATICS. A solid figure, or polyhedron, that has four triangular surfaces.

Any triangular pyramid is a TETRAHEDRON.

thalamus \'thal-ə-məs\ *n.*

ANATOMY. In man, the part at the base of the brain that receives and transmits certain impulses from sense organs to the cerebral cortex of the brain.

The two optic nerves join shortly before they enter the THALAMUS.



theodolite \thē-'äd-ᵊl-,īt\ *n.*

ENGINEERING. An instrument used for measuring horizontal and vertical angles. It usually consists of a telescope, graduated circles on which the readings are made, a level, a horizontal compass and the necessary supporting structures.

A THEODOLITE *is used to follow the path of a weather balloon sent aloft to determine wind direction and speed.*

theorem \'thē-ə-rəm\ *n.*

MATHEMATICS. A statement that requires a proof; also, a statement or sentence that may be deduced from a set of definitions, postulates and theorems already proved.

One geometric THEOREM *states that if two sides of a triangle are equal, then the angles opposite the equal sides are equal.*

theoretical science \,thē-ə-'ret-i-kəl 'si-ən(t)s\

The phase of science that involves the formulation of new theories on the basis of existing knowledge and that does not usually involve experimentation, as contrasted with experimental science. Theoretical science sometimes means those phases of science not dealing with the applications of scientific knowledge.

Probably the most important contributions to THEORETICAL SCIENCE *during the first half of the twentieth century were those made by Albert Einstein.*

THEODOLITE (TRANSIT)

theory \'thē-ə-rē\ *n.*

An established or accepted explanation of relationships among observed scientific facts, events or phenomena; also, the result of a verified hypothesis; also, sometimes, a hypothesis concerned with major phenomena.

The wave THEORY *of light is used in explaining reflection, while the quantum theory is used in explaining certain other kinds of light behavior, such as the photoelectric effect.*

theory of relativity \'thē-ə-rē əv ,rel-ə-'tiv-ət-ē\

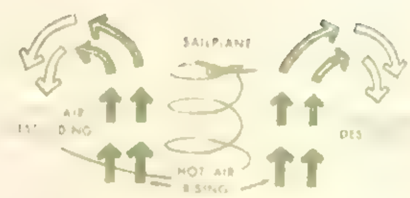
PHYSICS. Another term for relativity theory. See *relativity theory.*

therapeutics \\,ther-ə-'pyüt-iks\\ *n.*
MEDICINE. That part of medical science that deals with the treatment of disease.

THERAPEUTICS *may include the regulation of diet and exercise, as well as the use of medicines.*

thermal \\'thər-məl\\
1. EARTH SCIENCE (N.). A rising warm air current; a convection current. 2. (Adj.). Referring to, or caused by, heat.

Sailplane pilots utilize a THERMAL *to remain aloft.*



THERMAL CONVECTION

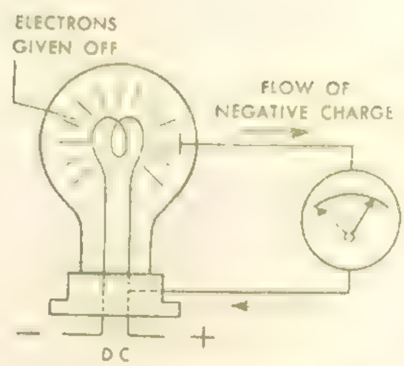
thermal barrier \\'thər-məl 'bar-ē-ər\\
ASTRONAUTICS. Another term for heat barrier. See *heat barrier.*

thermal conductivity \\'thər-məl ,kän-,dək-'tiv-ət-ē\\
PHYSICS. The measurable ability of a substance to transmit heat.

THERMAL CONDUCTIVITY *is expressed as the quantity of heat that can pass through a plate of the material in a given time, the plate being of given area and thickness and the two faces of the plate differing in temperature by one degree.*

thermal convection \\'thər-məl kən-'vek-shən\\
PHYSICS. The transfer of heat through a fluid (liquid or gas) by circulation of the fluid. Thermal convection results from the fact that warm fluid is less dense than cool fluid and will rise in cooler surrounding fluid.

On summer days, fast-rising air currents caused by THERMAL CONVECTION *frequently make it possible for sailplanes or gliders to gain altitude when in free flight.*



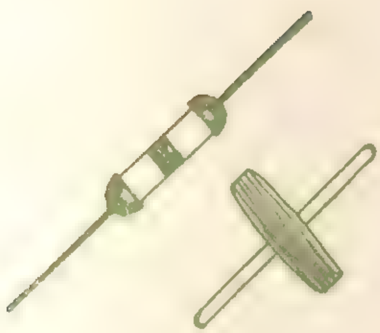
THERMIONIC EFFECT

thermal radiation \\'thər-məl ,rād-ē-'ā-shən\\
PHYSICS. Energy in the form of heat.

Infrared rays, visible light rays and ultraviolet rays are kinds of THERMAL RADIATION.

thermionic effect \\,thər-(,)mī-'än-ik i-'fekt\\
PHYSICS. The giving off, or emission, of free electrons from an incandescent object, such as a wire carrying an electric current. Under certain conditions, positive ions may be emitted.

Thorium produces a greater THERMIONIC EFFECT *than most metals and is, therefore, frequently coated on tungsten filaments in electron tubes to produce a cloud of free electrons.*



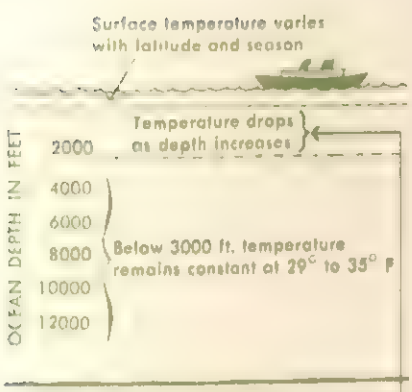
THERMISTOR

thermistor \\'thər-ˌmis-tər\\ *n.*
ENGINEERING. A temperature-influenced resistor used in TV circuits and in some other devices.

The electrical resistance of a THERMISTOR *decreases as the temperature of the metallic oxide of which it is made increases.*

thermochemistry \\ˌthər-mō-'kem-ə-strē\\ *n.*
CHEMISTRY. The study of heat energy absorbed or produced by chemical reactions.

Experiments in THERMOCHEMISTRY *have shown that one pound of coal (carbon) burned completely produces about three million calories.*



THERMOCLINE

thermocline \\'thər-mə-ˌklīn\\ *n.*
EARTH SCIENCE. A layer of water, found at varying depths, in which the temperature decreases faster than in the layers above and below.

A THERMOCLINE *may be either a permanent or a seasonal feature of a body of water.*

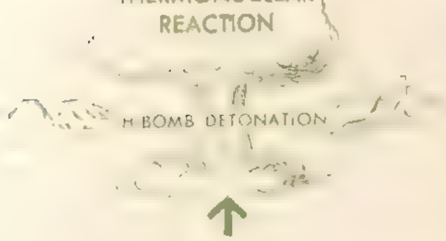
thermocouple \\'thər-mə-ˌkəp-əl\\ *n.*
PHYSICS. Two different metals in contact with each other that produce an electrical voltage when heated; commonly, two wires of different metals twisted together to form a junction that, when heated or cooled, produces a potential difference, or voltage, between the free ends of the wires.

A THERMOCOUPLE *connected to a galvanometer may be used to measure temperature.*

thermodynamics \\ˌthər-mə-(ˌ)dī-'nam-iks\\
PHYSICS. A branch of physics dealing with the relationships of heat energy to mechanical and other forms of energy.

The first law of THERMODYNAMICS *states that energy cannot be created or destroyed.*

THERMONUCLEAR REACTION

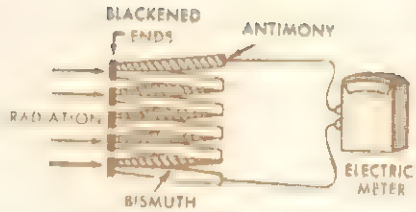


thermonuclear reaction \\ˌthər-mō-'n(y)ü-klē-ər rē-'ak-shən\\
CHEMISTRY and PHYSICS. A reaction between the nuclei of two atoms that forms a larger nucleus and usually a free subatomic particle. Thermonuclear reactions release a large amount of energy, as compared with chemical reactions between atoms, and require very high temperatures (around 400 million degrees Centigrade) to start.

A THERMONUCLEAR REACTION *between two deuterons (heavy hydrogen nuclei) forms one helium nucleus and one neutron and releases about 3 million electron volts of energy.*

thermopile \'thər-mə-ˌpīl\ *n.*
PHYSICS. A device that converts heat energy directly into electrical energy.

A THERMOPILE *connected to an electric meter is frequently used to measure radiant heat energy from the sun.*



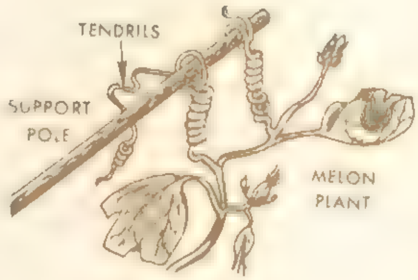
THERMOPILE

thermoplastic \ˌthər-mə-'plas-tik\ *adj.*
CHEMISTRY and PHYSICS. Referring to a solid substance that can be softened by heating without first undergoing chemical decomposition, as glass and certain synthetic polymers (plastics).

Because polyethylene is a THERMOPLASTIC *substance, it can be molded in many shapes.*

thermosetting \'thər-mō-ˌset-iŋ\ *adj.*
CHEMISTRY. Referring to a solid substance that, when heated, decomposes before it softens; frequently, describing certain types of synthetic polymers, or plastics, that cannot be molded after they have been formed; see *thermoplastic.*

Bakelite, the first synthetic plastic, is a THERMOSETTING *substance.*



THIGMOTROPISM

thiamine \'thī-ə-ˌmēn\ *n.*
CHEMISTRY and MEDICINE. One of the compounds (B_1) making up the vitamin B complex and present in such foods as beans, green vegetables, egg yolk, liver and corn meal. A deficiency of it in the diet tends to cause beriberi.

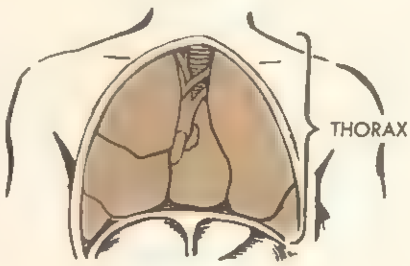
THIAMINE *and other vitamins are added to enriched flour and other cereal products.*

thigmotropism \thig-'mä-trə-ˌpiz-əm\ *n.*
BIOLOGY. The movement of an organism, or any part of an organism, in response to touch or contact.

Positive THIGMOTROPISM *is demonstrated by plant tendrils that wrap around an object within minutes after contact with it.*

thorax \'thō(ə)r-ˌaks\ *n.*
ANATOMY and ZOOLOGY. The part of the body between the head and abdomen; in insects, the body part that usually has three pairs of legs and, often, two pairs of wings.

In mammals, the cavity of the THORAX *is separated from the abdominal cavity by the diaphragm.*



THORAX

threshold \'thresh-ˌ(h)ōld\ *n.*
1. PHYSIOLOGY. The lowest degree of stimulation that will produce a sensation. 2. PHYSICS. The lowest intensity of energy,

such as temperature or electrical voltage, at which a given effect happens.

The THRESHOLD *of hearing varies with the pitch of sound.*

thrombin \'thräm-bən\ *n.*

PHYSIOLOGY. A blood enzyme that aids in forming blood clots. It is formed from the blood protein, prothrombin, and changes fibrinogen into fibrin during clotting.

THROMBIN *is present in blood that escapes from a wound or cut but is not present in circulating blood.*

THRUST FAULT

thrombocyte \'thräm-bə-,sīt\ *n.*

ANATOMY. Another term for blood platelet. See *platelet.*

thrombosis \thräm-'bō-səs\ *n.*

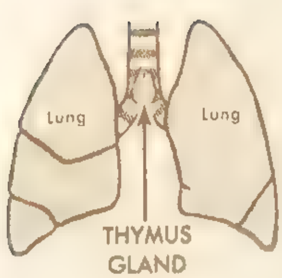
PHYSIOLOGY. The formation of a fixed blood clot within the circulatory system.

In coronary THROMBOSIS, *a clot forms in the coronary artery and prevents blood from reaching part of the heart muscles.*

thrust fault \'thrəst 'fȯlt\

EARTH SCIENCE. A fracture in the earth's crust, in which the hanging wall has been moved up relative to the footwall; also, a low-angle fracture in rock layers where one section is forced up over a corresponding section along the plane of the fracture; also called a reverse fault.

A THRUST FAULT *is caused by forces that compress or shorten the earth's crust.*



thunder \'thən-dər\ *n.*

EARTH SCIENCE. The sound resulting when lightning heats the air along its path, causing the air to expand suddenly and producing a sound wave.

If THUNDER *is heard five seconds after lightning is seen, the lightning was about one mile away.*

thymus gland \'thī-məs 'gland\

ANATOMY. A ductless, glandlike body located in the chest cavity near the base of the neck.

The THYMUS GLAND *is largest during early childhood and normally decreases in size in later years.*

thyroid gland \'thī(ə)r-,ȯid 'gland\

ANATOMY and PHYSIOLOGY. An endocrine gland in the neck, made up of two connected lobes, one on each side of the

trachea. It controls and regulates much of the metabolism of the body.

Iodine is necessary for normal functioning of the THYROID GLAND.

thyroxine \thī-'räk-,sēn\ *n.*

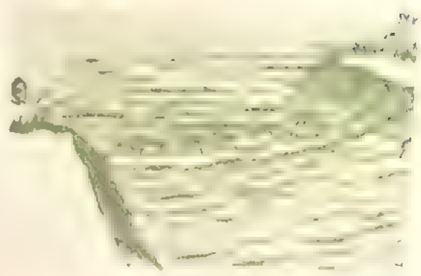
PHYSIOLOGY. A hormone (organic catalyst or chemical regulator) that is produced by the thyroid gland.

THYROXINE *was first isolated by extracting it from the thyroid glands of animals and was later prepared synthetically.*

tidal bore \'tīd-ᵊl 'bō(ə)r\

EARTH SCIENCE. A tide-caused wave with an abrupt front that flows rapidly from the ocean up a river or estuary.

In the Bay of Fundy and the Amazon River, a TIDAL BORE *occurs with each high tide.*



TIDAL BORE

tidal theory \'tīd-ᵊl 'thē-ə-rē\

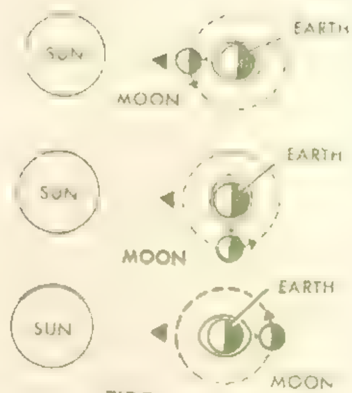
ASTRONOMY. A theory of the origin of the solar system, based on the assumption that, as a star approached the sun, a tidal wave of gaseous material occurred on the sun's surface and that part of this material was pulled away from the sun and later condensed as planets and natural satellites.

According to the TIDAL THEORY, *as well as several other theories dealing with the origin of the solar system, the earth formed from a hot, gaseous mass.*

tidal wave \'tīd-ᵊl 'wāv\

EARTH SCIENCE. The rise and fall of the ocean surface because of the gravitational attraction of the sun and moon. Tidal wave is sometimes used incorrectly as a synonym for tsunami.

A TIDAL WAVE *is most noticeable along gradually-sloping seashores where the shoreline moves landward at high tide and seaward at low tide.*



TIDE

tide \'tīd\ *n.*

EARTH SCIENCE. The rise and fall of the surface of the sea, especially noticeable along shores and in bays and gulfs. Tides occur twice in 24 hours and 52 minutes and are caused by the gravitational attraction of the sun and moon.

The TIDE *in the open sea and along straight coastlines varies by only a few feet, while in places like the Bay of Fundy, it may vary as much as 50 feet.*

till \'til\ *n.*

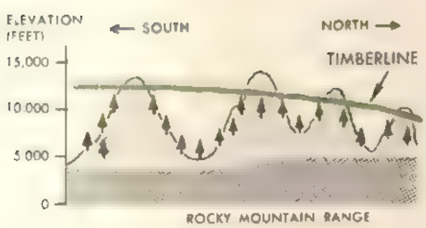
EARTH SCIENCE. A glacial deposit containing unassorted rocks and earth materials; also called boulder clay; see *drift.*

TILL *is deposited directly from glacial ice rather than from streams flowing out of the glacier.*

timberline \'tim-bər-ˌlīn\ *n.*

BIOLOGY and EARTH SCIENCE. An area above which (on mountainsides) or beyond which (at higher north and south latitudes) trees do not grow, primarily because of low temperatures.

The TIMBERLINE *in New Mexico occurs at approximately 12,000 feet, but in northern Canada it is at sea level.*



TIMBERLINE

time zones \'tīm 'zōnz\

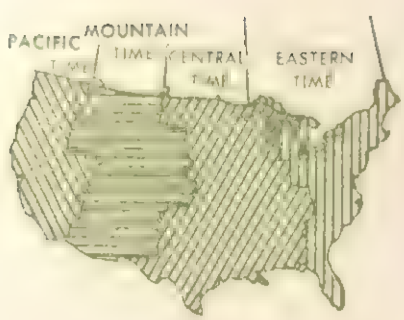
The 24 divisions on the earth, each about 15 degrees wide and centered on a meridian. Each division has a standard time based on the solar time of the central meridian.

The line between two TIME ZONES *often follows state boundaries or some other arbitrary line convenient to the people living near the line.*

tin \'tin\ *n.*

CHEMISTRY. A soft, silvery, metallic element that does not react readily at ordinary temperatures except with strong acids. It is used in many alloys that have low melting points, such as solder. Symbol, Sn; atomic number, 50; atomic weight, 118.69.

TIN *is used as a corrosion-resistant coating on thin sheet metal that is formed into cans for packaging food, oil and other substances.*



TIME ZONES

tincture \'tiŋ(k)-chər\ *n.*

CHEMISTRY and MEDICINE. An alcoholic solution of a drug or other chemical substance.

TINCTURE *of iodine is sometimes used as an antiseptic on minor skin abrasions or cuts.*

tissue \'tish-(ˌ)ü\ *n.*

ANATOMY and ZOOLOGY. A group of cells having similar structures and performing special, as well as similar, functions.

A TISSUE *is made up of cells, while an organ is made up of tissues.*

tissue culture \\'tish-(ˌ)ü 'kəl-chər\\

BIOLOGY. A technique for growing single cells or detached pieces of tissue from the body of an organism, usually kept in glass cells containing sterile, nutrient media at specific temperatures.

Cells kept alive and growing in a TISSUE CULTURE *have the characteristic of not degenerating with age, as they would if they remained in the organism.*

TISSUE CULTURE (connective tissue)

titer \\'tīt-ər\\ *n.*

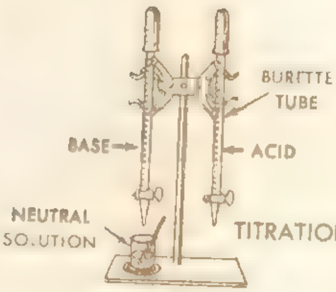
CHEMISTRY. The concentration of a solution as determined by titration, generally expressed as the normality or the number of grams of dissolved ion, element or compound per unit of volume of the given solution; also, the melting point of fatty acids released from fats by saponification.

Laboratories often use an automatic titration machine to determine the TITER *of a solution.*

titration \\tī-'trā-shən\\ *n.*

CHEMISTRY. The measured addition of a solution of known concentration to a solution of unknown concentration with which it reacts. The operation is frequently done with a burette; see *burette.*

TITRATION *of a base with an acid is often necessary in carrying out chemical analyses.*



TITRATION

tolerance \\'täl(-ə)-rən(t)s\\ *n.*

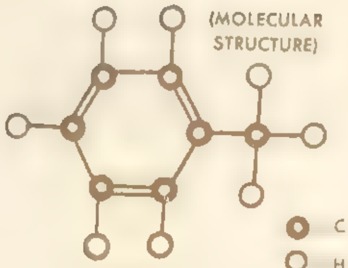
1. MEDICINE. The ability of the body to endure the presence of some toxin or irritant without ill effects. 2. ENGINEERING. The small variation in size, weight or other characteristics that a manufactured product may have and still be useful for a given purpose.

A beekeeper may develop a TOLERANCE *for the formic acid in a bee sting after he has been stung a number of times.*

toluene \\'täl-yə-ˌwēn\\ *n.*

CHEMISTRY. $C_6H_5CH_3$. A colorless liquid that does not dissolve in water. It is an aromatic hydrocarbon used as a solvent and as a beginning substance in the manufacture of many chemical products; also called toluol.

The explosive trinitrotoluene (TNT) is made from TOLUENE.



TOLUENE

ton \\'tən\\ *n.*

MATHEMATICS. A unit of weight equal to 2,000 pounds in the United States, Canada and the Union of South Africa and to 2,240 pounds in Great Britain.

The American TON *is often called the short ton, while the British ton is called the long ton.*

tonsils \'tän(t)-səlz\ *n.*
ANATOMY. The two small lymph glands located in the back of the throat and believed to produce phagocytes (white corpuscles) that destroy bacteria in the mouth and pharynx.

TONSILS *that become seriously infected during childhood are sometimes removed by surgery.*

tonus \'tō-nəs\ *n.*
PHYSIOLOGY. The slight, continuous contraction of skeletal muscles that aids in body posture and in the process of returning blood and lymph to the heart; also called muscle tone.

During TONUS, *the muscle fibers of a large muscle contract alternately, not together.*


TONSILS

tooth \'tüth\ *n.*
ANATOMY and ZOOLOGY. In the vertebrate animals, one of the bonelike structures in the jaws used for tearing and chewing food.

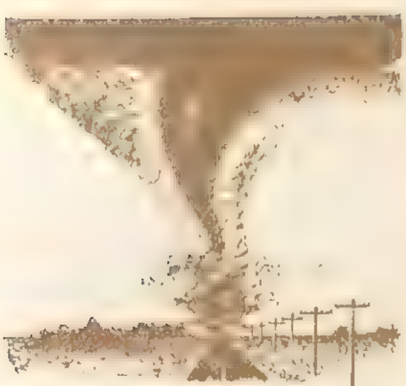
In children, a deciduous or temporary TOOTH *will be replaced by a permanent tooth.*

topography \tə-'päg-rə-fē\ *n.*
EARTH SCIENCE. The study and description of the physical features of the earth's surface, including their representation on maps; also, the physical features themselves.

The TOPOGRAPHY *of an area changes naturally by erosion and artificially by the works of man.*

topology \tə-'päl-ə-jē\ *n.*
MATHEMATICS. The part of geometry in which those properties are studied which are not changed, or which are invariant, when changes, or transformations, in size and shape occur.

In TOPOLOGY, *such figures as circles, ellipses, squares and triangles are all considered simple closed curves.*


TORNADO

topsoil \'täp-ˌsȯil\ *n.*
EARTH SCIENCE. A thin layer, usually 6 to 18 inches deep, of loose surface material whose volume is about half mineral and rock particles and half humus and air or water-filled spaces.

Erosion is the major factor that man attempts to control in conserving TOPSOIL.

tornado \tȯr-'nād-(ˌ)ō\ *n.*
EARTH SCIENCE. A relatively-small but violent storm accompanied by a funnel-shaped cloud in which wind may whirl at

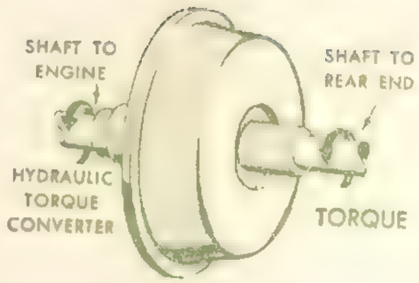
speeds of several hundred miles per hour. Tornadoes occur over land under certain combinations of atmospheric conditions, such as low pressure, high temperature and high humidity.

The very low pressure inside the funnel of a TORNADO *is a major cause of the damage done when the funnel touches the earth.*

torque \'tȯ(ə)rk\ *n.*

PHYSICS. A turning or twisting force; also, a tendency for an object to turn around a point within itself.

The drive shaft of an automobile must be made of very strong material to withstand the TORQUE *produced by the engine.*



torr \'tȯ(ə)r\ *n.*

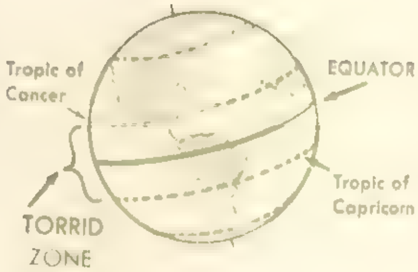
PHYSICS. A unit of pressure very nearly the same as the pressure required to support a column of mercury 1 mm. high at 0° C.

The TORR *was named after Evangelista Torricelli, who also invented the barometer.*

Torrid Zone \'tȯr-əd 'zōn\

EARTH SCIENCE. The area bordering the equator and extending 23½ degrees north and south to the Tropics of Cancer and Capricorn. It is the largest of the earth's climatic zones.

The TORRID ZONE *has a higher average temperature since the sun's rays are nearly vertical there all year.*



torsion \'tȯr-shən\ *n.*

PHYSICS. A twisting force; also, the act of twisting; also, a state of being twisted.

The drive shaft of a car must be able to withstand TORSION.

torsion balance \'tȯr-shən 'bal-ən(t)s\

PHYSICS. A sensitive device used to measure small forces. It utilizes a fiber made of steel or quartz that is twisted, the amount of twist being a measure of the force under consideration.

A TORSION BALANCE *has been used to measure the pressure of a beam of light striking an object.*

totality \tō-'tal-ət-ē\ *n.*

ASTRONOMY. The period during a solar eclipse when the light of the sun is completely cut off by the moon; also, that period during a lunar eclipse when the umbra of the earth's shadow completely covers the moon.

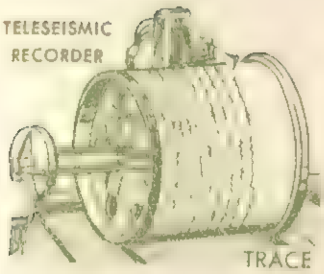
During a total solar eclipse, maximum TOTALITY *for a given area would be approximately 7 minutes, while totality of a lunar eclipse may be as long as 1½ hours.*

toxic \'täk-sik\ *adj.*
MEDICINE. Referring to, or caused by, a poison; poisonous.

Disease-producing organisms usually give off TOXIC *substances that are waste products of their own life processes.*

toxicology \ˌtäk-sə-'käl-ə-jē\ *n.*
MEDICINE. That branch of science that deals with the chemical and physical nature, origin and preparation of poisons, and with their effect on given plants and animals.

The science of TOXICOLOGY *includes a study of antidotes and their physiological effects.*

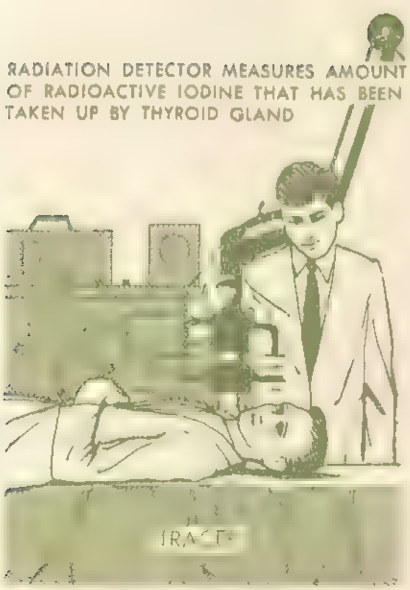


toxin \'täk-sən\ *n.*
BIOLOGY. Any poison produced and secreted by an animal or plant organism as a metabolic by-product. When disease is caused by the toxin of parasites, the host may produce counteracting antibodies called antitoxin.

Alcohol is a TOXIN *produced by yeast that feeds on sugar.*

toxoid \'täk-ˌsȯid\ *n.*
MEDICINE. A toxin that has been treated chemically to render it safe but that retains its ability to stimulate the growth of antibodies.

A TOXOID *may be administered by injection to immunize a person against a disease.*



trace \'trās\ *n.*
1. CHEMISTRY. A very small quantity, sometimes unmeasurable, of a substance, characteristic or quality. 2. ENGINEERING. The graph produced by an instrument that records such variable conditions as temperature or pressure.

The air in large cities usually contains a TRACE *of carbon monoxide.*

trace elements \'trās 'el-ə-mənts\
BIOLOGY. Elements needed in only minute quantities by animals and plants.

The absence of TRACE ELEMENTS, *such as cobalt and molybdenum, in pasturelands has been found to be a cause of wasting in grazing sheep.*

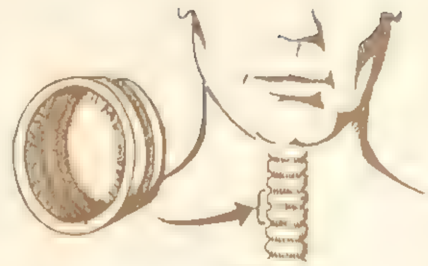
tracer \'trā-sər\ *n.*
CHEMISTRY and PHYSICS. A substance added to a second substance in which it is normally not present so that the second substance may be followed through a series of physical, chemical

or biological processes; frequently, a radioactive atom that replaces a nonradioactive atom in a molecule of a compound; see *radioisotope* and *tagged atoms*.

Radioactive iodine has been used as a TRACER *to analyze the action and determine the size of the human thyroid gland.*

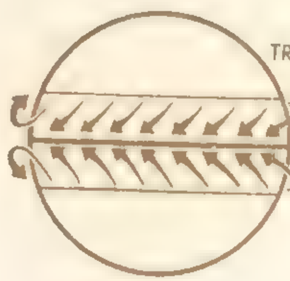
trachea \'trā-kē-ə\ *n.*
ANATOMY and ZOOLOGY. The tube that begins at the larynx and extends to the bronchi, making up the air passage to and from the lungs; also called the windpipe.

The TRACHEA *in a vertebrate animal is composed of rings of cartilage and membranes and is lined with cilia.*


TRACHEA

trade winds \'trād 'windz\
EARTH SCIENCE. Prevailing winds in the regions of latitudes 30 to 35 degrees north and south of the equator that blow toward the low-pressure equatorial region. They are winds that move from the horse latitudes toward the doldrums.

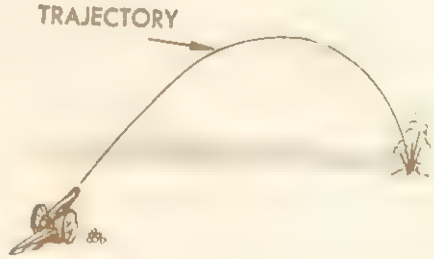
The TRADE WINDS *blow from the northeast in the Northern Hemisphere and from the southeast in the Southern Hemisphere.*



TRADE WINDS

trajectory \trə-'jek-t(ə-)rē\ *n.*
1. ASTRONOMY and ENGINEERING. The path of a moving body. 2. MATHEMATICS. A curve cutting all curves or surfaces of a given family at the same angle, as a circle with its center at the origin is a trajectory that cuts, at right angles, the family of straight lines passing through the origin.

The TRAJECTORY *of a bullet fired from a gun has a parabolic shape.*

TRAJECTORY


transceiver \tran(t)s-'ē-vər\ *n.*
ENGINEERING. A radio device that receives and also transmits, using many of the same tubes or transistors for both functions.

A walkie-talkie is a short-range TRANSCEIVER.

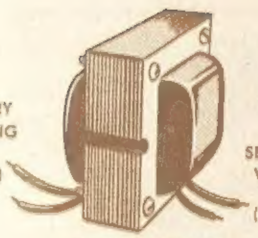
transcendental number \,tran(t)s-,en-'dent-ᵊl 'nəm-bər\
MATHEMATICS. An irrational number that is not algebraic, or that cannot be expressed as a root of an equation with rational coefficients.

The most familiar TRANSCENDENTAL NUMBER *is π, but the logarithms of most numbers are also transcendental numbers.*

transducer \tran(t)s-'d(y)ü-sər\ *n.*
ENGINEERING. A device that receives power from one sys-

tem, changes it in some way, and then transmits it to another system.

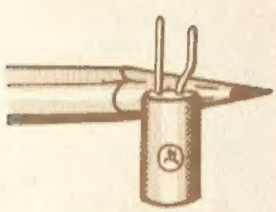
A microphone is a TRANSDUCER *that passes on electrical energy modified by sound waves.*



TRANSFORMER

transformer \tran(t)s-'fȯr-mər\ *n.*
ENGINEERING. A device that changes the voltage of an alternating electrical current. A transformer contains no moving parts and in its simplest form is made of two coils of wire (primary and secondary) that are insulated from each other. Alternating current in the primary coil induces a current in the secondary coil. A transformer may also be a device that transfers electrical energy from one circuit to another without an actual electrical connection between them.

Most toy electric trains have a TRANSFORMER *to reduce the voltage of the house current to the voltage at which the train motor operates.*

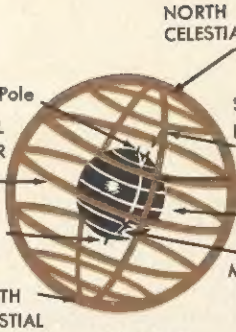

TRANSISTOR

transfusion \tran(t)s-'fyü-zhən\ *n.*
MEDICINE. The introduction of whole blood or plasma directly into the bloodstream.

A TRANSFUSION *is sometimes necessary in treating shock.*

transistor \tranz-'is-tər\ *n.*
ENGINEERING and PHYSICS. A small, solid object used to control, amplify, or control and amplify, small electrical currents and commonly used in radios instead of an electron tube. It utilizes a semiconductor, such as germanium or silicon, to change its conductivity; see *semiconductor.*

A TRANSISTOR *uses less power, produces less heat, takes up less space and produces less static than does an electron tube.*



TRANSIT
(OF STAR)

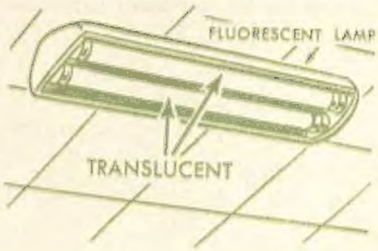
transit \'tran(t)s-ət\ *n.*
1. ASTRONOMY. The crossing of a celestial body over the meridian of a specific location; also, the passage of a celestial body across the field of a telescope; also, the passage of a celestial body across the disk of a larger celestial body. 2. ENGINEERING. A device used in surveying to measure vertical and horizontal angles; see *theodolite.*

The stars make a TRANSIT *every 23 hours and 56 minutes, while the moon makes a transit at intervals of approximately 24 hours and 50 minutes.*

transition elements \tran(t)s-'ish-ən 'el-ə-mənts\
CHEMISTRY. A group of metallic elements with atomic numbers 23 through 31, 40 through 49 and 72 through 81 inclusive. They include such elements as iron, silver, copper and chromium,

and most form colored compounds. Transition elements have an incomplete inner electron shell; see *electron shell* and table, page 620.

The TRANSITION ELEMENTS *are so named because, on the periodic table, they represent a link between the elements that tend to gain electrons and those that tend to lose electrons.*



translucent \tran(t)s-'lüs-ᵊnt\ *adj.*
Referring to a substance that partially transmits light rays but diffuses them so that things seen through it are not clearly distinguishable.

The tubes for fluorescent lights are made of TRANSLUCENT *materials.*

transmutation \ˌtran(t)s-myü-'tā-shən\ *n.*
CHEMISTRY and PHYSICS. A process by which one element changes into another. It may occur naturally by radioactive decay, as when radium changes into polonium, or it may be caused artificially, as when a positively-charged subatomic particle is shot into the nucleus of an atom.

By TRANSMUTATION, *it is possible to change other elements into gold, but the cost of the process is more than the value of the gold produced.*

TRANSPARENT

transparent \tran(t)s-'par-ənt\ *adj.*
Referring to a substance that transmits light rays and through which objects can be clearly distinguished; also, referring to a substance that transmits electromagnetic radiation, such as X rays and gamma rays.

Safety glass contains a sheet of shatterproof, TRANSPARENT *plastic.*

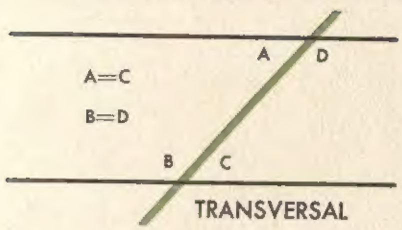
transpiration \ˌtran(t)s-pə-'rā-shən\ *n.*
BOTANY. The loss of water by evaporation from leaves and other plant parts exposed to the air.

Plants lose much more water through TRANSPIRATION *than they use in the food-making process of photosynthesis.*

TRANSPIRATION

transponder \tran(t)s-'pän-dər\ *n.*
ENGINEERING and PHYSICS. A type of transceiver that replies to an incoming signal by transmitting a reply, usually coded.

One kind of TRANSPONDER *transmits a code to aircraft that indicates to the pilot his distance from the transponder.*



TRANSVERSAL

transpose \tran(t)s-'pōz\ *v.*

MATHEMATICS. To eliminate a given term from a member of an equation by adding its additive inverse to both members of the equation. Transposition consists of moving a term from one side of an equation to the other and changing its sign.

In the solution for x in the equation $3x - 2 = 5x - 8$, the first step may be to TRANSPOSE *-2 and $5x$ by writing $3x - 5x = -8 + 2$.*

transuranium elements \ˌtran-shə-'rā-nē-əm 'el-ə-mənts\

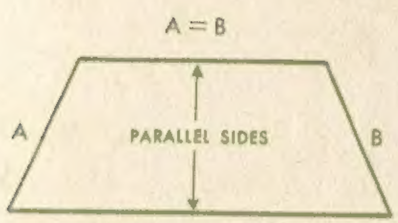
CHEMISTRY. Elements with atomic numbers larger than that of uranium; those elements with atomic numbers of 93 and higher.

All the TRANSURANIUM ELEMENTS *are radioactive.*

transversal \tran(t)s-'vər-səl\ *n.*

MATHEMATICS. A line that intersects two or more lines.

If two parallel lines are cut by a TRANSVERSAL, *the alternate interior angles are equal.*



TRAPEZOID
(ISOSCELES)

transverse \tran(t)s-'vərs\ *adj.*

1. ANATOMY. Referring to a part or structure that lies at right angles to the long axis of the body or of an organ. 2. MATHEMATICS. The axis of a conic, particularly of a hyperbola, that contains the foci.

The TRANSVERSE *colon crosses to the left side of the abdomen.*

transverse wave \tran(t)s-'vərs 'wāv\

PHYSICS. A type of wave causing the particles of the material, or medium, through which the wave passes to vibrate at right angles to the path of the wave, as distinguished from a longitudinal wave that causes particles of the medium to vibrate in the same direction the wave travels.

The wave caused by dropping a stone in a quiet pond is approximately a TRANSVERSE WAVE.

TRAPROCK
(BASALT)

trapezoid \'trap-ə-ˌzȯid\ *n.*

MATHEMATICS. A four-sided figure, or quadrilateral, that has two parallel sides called bases.

A TRAPEZOID *whose nonparallel sides are equal is called an isosceles trapezoid.*

traprock \'trap-ˌräk\

EARTH SCIENCE. A dark-colored, fine-grained, igneous rock often found in large, sheetlike masses, as basalt and diabase.

Basalt, a type of TRAPROCK, *is often crushed and used in building roads.*